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THE PROBLEM OF NOMENCLATURE FOR EXTRUSIVE IGNEOUS ROCKS[1]

by

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An opinion has become well established among petrographers that the nomenclature of extrusive igneous rocks has an arbitrary character and no logical basis (F. Yu. Levinson-Lessing [4, 5]) and that there is no systematic rock classification (A. N. Zavaritskiy, [2]).

Such an opinion is only partly true at best because the extrusive rock nomenclature is related quite clearly to the geologic history of the Earth and to development of geologic sciences even though it may not be systematic.

There are two distinct principles underlying nomenclature in the modern petrography of extrusive igneous rocks.

The first of these principles, established by the foremost German petrographers, F. Zirkel [12, 13] and Rosenbusch [10, 11], classifies extrusives as paleovolcanic and neovolcanic according to their age, which in Central Europe corresponds to pre-Mesozoic and post-Mesozoic.

The second principle was established by American petrographers, Dana [8] and Jackson [9], who differing from the European school of thought disregarded the age element in their classification and adopted a singular nomenclature of extrusives with no regard for age or the state of lava preservation.

European geologists followed Rosenbusch, although with some exceptions as we shall see, and favored the dual nomenclature of extrusives for a long time. Some geologists still favor this system. Geologists of both Americas, Japan, China and Australia use the singular nomenclature, as originated by Dana.

This diversity of opinions on extrusive rock nomenclature is perfectly understandable from the historical point of view. It is not an accident but ties in with the peculiarities of the development of geologic thinking in Europe (or more broadly in the eastern hemisphere) and in the Americas (the western hemisphere).

Caledonian, Hertzian and Alpine tectonic movements, coincident with plutonic and volcanic stages of magmatic activity, are typical of the post-Cambrian history of Central Europe where Zirkel and Rosenbusch evolved their petrographic principles of classification and nomenclature. European, particularly German and Austrian, geologists of the nineteenth century frequently observed both very old (Precambrian and lower Paleozoic) and very young (Pliocene and even Pleistocene) extrusives combined in the same region. In some instances, lavas, several hundred million if not several billion years apart, differed considerably in the extent of de-vitrification and in the number of minerals constituting them. A conviction that such differences were due to the nature of lavas and should, therefore, be reflected in the nomenclature led them to formulation of the dual nomenclature for extrusives. Paleozoic porphyrite and quartz porphyry were made analogous to Cenozoic andesite, dacite, liparite, and so forth.

Entirely different historical events were recognized in post-Cambrian developments in countries of the western hemisphere. Different phases of Mesozoic folding played a significant role in evolution of these lands. Thus, in addition to European caledonides, hertzianides and alpinides, mesozoides were distinguished together with their plutonic and volcanic complexes.

This difference in the effect of geologic history is significant not only in solution of geotectonic problems but also in development of petrographic nomenclature. Intensity of natural post-magmatic alteration of volcanic rocks, which was termed by M. A. Usov [7] "diagenetic greenstone transformation" increased very gradually in those countries from Cenozoic through Mesozoic to Paleozoic lavas. No gaps could be found in this

[1] K voprosu o nomenklature effuzivnykh gornykh porod.

transition from one rock to another in the countries of the western hemisphere. Therefore, there has never been any reason to differentiate extrusives of different ages. Geologists of the western hemisphere, unlike European geologists, have always regarded basalt and rhyolite to be the volcanic equivalents of gabbro and granite despite their ages or alteration of one or another lava.

Such are the historical settings that conditioned the development of singular and dual nomenclatures of extrusive rocks.

The rapid development of petrography, which characterized the end of the nineteenth century, was paralleled by the development of petrographic nomenclature. The numbers of newly discovered petrographic species and varieties increased rapidly, the nomenclature becoming ever more flexible and richer. However, there were complications in the nomenclature of extrusives due to the influence of the European system with its parallel names for pre- and post-Mesozoic lavas. Some names remained virtually the same for ancient lavas while the number of names for younger lavas increased rapidly. A whole array of new names appeared for rocks of this younger group: andesite-basalt, liparite-dacite, oceanite, muggearite, tholeite and others, there existing no equivalents among rocks of the older group. This quickly wrecked all parallelism in evolution of the two parts of the dual nomenclatural scheme and substantially slowed down progress in petrography, promoting at the same time the development of imaginative ideas as to the absence in ancient times of lavas analogous to modern ones.

Additional complications were purely geologic in nature. In Europe, and particularly in regions of folded Alpine systems both Mesozoic lava and Mesozoic tectonics were recognized at a very early stage. Later, Mesozoic phases of geotectonic history were to receive equal attention in the Asiatic part of the Eurasian continent.

Extrusive rock nomenclature had to be revised in the light of new geologic knowledge. Terms that originally were coined for Paleozoic lavas had to be applied to Mesozoic lavas. Since then, one part of the nomenclatural scheme was used in connection with pre-Cenozoic extrusives and the other part with those of the Cenozoic. The line of demarcation between the two was arbitrarily fixed at the end of the Danion and the beginning of the Paleocene.

Then there arose an even greater complication. Among relatively old rocks, e.g., Upper Cretaceous age, alteration seemed to be more intense than the alteration of younger rocks of, e.g., Paleogene age. Seeking a solution to this problem Broegger (1894) proposed to drop the age concept in the classification of extrusives, nevertheless preserving the dual nomenclature for altered and unaltered lavas, i.e., the Paleo- and Ceno-types, respectively. Being a compromise, such a proposal did not give and could not give any criteria for distinguishing between the two groups and thus did not improve the situation. Thereafter there appeared in European petrographic literature Mesozoic and Paleozoic andesites on a par with Cenozoic porphyrite; both liparite and quartz porphyry, basalt and melaphyre, and other dual terms were described from a single outcrop.

The status of petrography at the beginning of the twentieth century could not be described in any other way but as a nomenclatural crisis. Many petrographers in some European countries began to look for a new solution to the problems. In many places — in England, France and the Scandinavian countries — the solution worked out was to reject entirely the dual nomenclature but to use the same terms, i.e., those originally intended for younger Ceno-type lavas because this nomenclature was best developed.

The situation was even more complicated in Russia (later in the Soviet Union). Petrographers, who worked mostly in the Asiatic part of the country with its extensive mesozoides, were convinced of a complete transition from the youngest to the oldest extrusives. This led to abandonment of the age principle (A.P. Karpinskiy [3], B.K. Polenov [6], P.I. Venyukov [1], and others).

However, such a great authority in the field of petrography as F. Yu. Levinson-Lessing followed Broegger in the latter's compromise of preserving the dual nomenclature minus its original basis — the age principle. We have already discussed the negative consequences of that compromise which retained all the disadvantages of dual nomenclature and did not diminish the disorderliness.

Later, A.N. Zavaritskiy [2] went even further than F. Yu. Levinson-Lessing to bring together two parallel lines of nomenclature for extrusives. He also rejected the age principle of the nomenclature and also retained the classification of lavas as Paleo- and Ceno- types but introduced the use of descriptive adjectives borrowed from the corresponding Ceno-types to denote varieties of Paleo-types. Examples are: andesitic porphyrite and basaltic porphyrite.

Such a proposal was progressive to a certain extent in that it allowed the use of such previously non-existent terms for description of Paleo-types as "andesite-basaltic

porphyrite," and "trachy-andesitic porphyrite." This has made the system more flexible.

A.N. Zavaritsky's system does not furnish any rational criteria for distinguishing Paleo- and Ceno-types. Moreover it hides the misconception of inherent differences existing between extrusives of different geologic ages, there being no actual need for recognition of two types. The very attempt made by Zavaritskiy to bring together etymologically the two series of nomenclature testifies to the dire necessity of elimination of one of these series.

The foregoing discussion indicates clearly that nomenclatural division of extrusives into "young" (Ceno-type) and "ancient" (Paleo-type) has been historically inherited by European, including Soviet, petrographers from the early stages of development of geology and petrography in Central Europe. This is a throwback which slowed the development of the nomenclatural apparatus even in the last century and which is an anachronism today.

The full liquidation of the entire nomenclatural scheme — in so far as Paleo-type lavas are concerned — aids clearing petrography from many superfluous terms and streamlines petrographic terminology. It should be stressed that elimination of the dual nomenclature of extrusives will not be painful at all because most Soviet, especially Siberian and Far-Eastern petrographers, have long since adopted the singular nomenclature of their own accord.

The tabulation that follows brings together the two series. Its left half is reserved for neo-volcanic (Ceno-type) extrusives and naturally includes "sub-volcanic" and dike rocks of porphyritic texture. The right half of the table characterizes "paleo-volcanic" (Paleo-type) rocks, the names of which should have been discredited long ago.

A comparison of both halves of this table illustrates at a glance the incomparably greater versatility and flexibility of the contemporary classification used by a majority of petrographers of the world for extrusives of any age. It also accentuates the extreme poverty and, therefore, the uselessness of that part of the nomenclature applicable to rocks shown on the right of the table.

This table does require certain reservations and clarification. The term "quartz porphyry" perhaps could be retained to denote granite porphyry which contains large quartz phenocrysts in a fine-graned matrix. The term

[2]Nevertheless, neither A.N. Zavaritskiy himself nor his followers have ever exploited this only advantage of the modernized nomenclature.

Nomenclatural tabulation of extrusives that are commonly divided into Paleo-type (Paleo-volcanic) and Ceno-type (Neo-volcanic) groups.

1. Liparite.	1. Quartz porphyry.
2. Soda-liparite.	2. Quartz keratophyre and oxy-keratophyre.
3. Liparite-dacite	3. *
4. Dacite.	4. Quartz porphyry.
5. Andesite-dacite.	5. *
6. Andesite.	6. Porphyrite.
7. Andesite-basalt.	7. *
8. Basalt.	8. Melaphyre, labradorite porphyrite, diabasic porphyrite, spilite.
9. Dolerite.	9. Diabase.
10. Alkali-trachyte.	10. Orthophyre, porphyry without quartz, feldspathic porphyry.
11. Trachy-liparite.	11. *
12. Trachy-dacite.	12. *
13. Trachy-andesite.	13. *
14. Trachy-basalt.	14. *
15. Soda and potash trachyte and trachy-liparite.	15. Soda and potash keratophyre.
16. Albitized: liparite, liparite-dacite, dacite, etc. up to basalt.	16. Albitophyre, quartz albitophyre, albite porphyry, plagiophyre.

* Equivalents lacking.

"porphyrites" might be similarly used for intrusive porphyritic rocks of dioritic and gabbroic composition. Terms like "diabase", "spilite" and "keratophyre" which are frequently used to denote either paleo-types or extrusives formed in sub-aqueous environments during early stages of evolution of geosynclinal basins might possibly be retained for use in this genetic sense. However, there is no justification whatsoever for the term "diabase" or "trap".

It is perfectly obvious that alteration of the rock might be described by the adjective "paleotypic" although it would have been preferable to use the word "altered" or "decomposed" which reflects the meaning better.

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DISTRIBUTION OF URANIUM AND THORIUM IN CERTAIN SINGLE PHASE INTRUSIVES OF TYAN'-SHAN' [1]

by

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This paper presents data on distribution of uranium and thorium in various zones in five single phase intrusives of Caledonian alaskite granite of Terskey Ala-Tau Range.

Variations in radioactivity of granitic intrusives formed from a common magma are explained by deep erosion, structure of the intrusion and intensity of autometamorphic and postmagmatic processes.

A relatively greater mobility of uranium, in comparison with that of thorium, has been noted in the process of intrusive emplacement.

* * * * *

The distribution of uranium and thorium within individual granitic massifs is essentially related to the problem of radioactivity of granites. Its importance was pointed out by Vernadsky [1]. Studies by Komlev [2] and Soloviyev [2], carried out in the thirties, and a more recent work by Ingham and Keevil [10] were investigations of this kind.

The first two [2, 5] furnished data on uranium distribution in the Malyukin granodioritic laccolith, where a very important feature was recognized for the first time — uranium enrichment in the upper part of the laccolith. The last work dealt with distribution of total alpha-radioactivity (U + Th) of nine granitic massifs. Radioactivity enrichment (U + Th) has been found to be restricted to border zones of larger intrusives — over 2 miles in diameter. Any such regularity was not found in smaller intrusives.

In the present paper, we discuss a part of the results of our investigations of granitic intrusives of Tyan'-Shan' which were carried out by us between 1947 and 1950. We will consider distribution of uranium and thorium in five single phase intrusives of Caledonian alaskite granite situated within the Terskey Ala-Tau Range.

These examples well illustrate variation in content, distribution and ratio of thorium and uranium in different massifs derived from the same, common magma, these variations being due to structure, depth of erosion and intensity of postpagmatic processes. Granites making up these intrusives, are of the same type and have identical petrographic and chemical composition. Their geologic attitude suggests their genesis from a common magma.

Age, determined by the argon method as 320 to 350 million years, is the same for all five — within limits of experimental error.

Before discussing distribution of uranium and thorium in these granites, methods of sampling and analysis should be reviewed in order to determine the basis for evaluation of obtained results.

1. SAMPLING OF GRANITES

Uranium and thorium are irregularly disseminated throughout granitic massifs. Their proportion varies not only with the individual zones in a given massif but often in two adjacent samples [7]. Therefore, to be representative, samples had to be composite consisting of no less than 8 to 10 pieces of granite and totalling 2 to 3 kilograms in weight. Quite a number of such composite samples had to be taken to permit evaluation of the entire massif or even one of its zones. The number of samples to be taken was determined from the coefficient of variation in uranium and thorium content and adjusted to

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[1] **Raspredeleniye urana i toriya v nekotorykh odnofaznykh intruziyakh Tyan'-Shanya.**

the desired precision of sampling [7].

Variations in content of radioactive elements in different granitic massifs and in different zones of the same massif are shown in Table 1.

These data are for massifs of different sizes. Terskey Ala-Tau is a large batholith, Sary-Bulak is a small massif, Sary-Maynok is a greissenitized stock. Values for "v" are nearly the same for both uranium and thorium for all massifs. However, they vary appreciably for different zones of the same massif, sharply rising toward the periphery. Uranium and thorium were determined indirectly as Ra and Thx. We used a modified method of radiochemical analysis devised by Starik [6]. Such indirect determination is admissible only when decay daughters of uranium and thorium are in equilibrium.

In unaltered monolithic eruptives radioactive equilibrium should theoretically exist but there may be some doubts of its existence. To check on this equilibrium, a number of uranium determinations were carried out in some granites by parallel radiochemical and fluorescent methods [9].

In all investigated cases, relatively unaltered granite was found to be practically in equilibrium and consequently it was possible to use indirect methods of analysis.

2. DISTRIBUTION OF URANIUM AND THORIUM IN VARIOUS GRANITIC MASSIFS

We will briefly quote summarized data on distribution of uranium and thorium in different zones of individual granitic massifs. Since some of these massifs have already been described elsewhere [3, 4], we shall limit ourselves here to generalizations which are a necessary basis for the conclusions given in this paper.

Groups of samples were taken approximately parallel to contacts of all massifs. Each zonal sampling consisted of several samples taken at approximately equal intervals. Each such individual sample consisted of 8 to 20 pieces of granite.

1) Dzhety-Oguz Intrusive [3]

This is a single phase, homogenous massif of Caledonian leucocratic granite. It has

Table 1

Massif	Number of Samples	σ		v		m		p	
		U	Th	U	Th	U	Th	U	Th
Terskey Ala-Tau	33	3,7	0,9	44	35	0,6	0,2	7	8
Sary-Maynok	10	5,5	1,1	33	28	1,7	0,3	10	8
Sary-Bulak	24	2,8	1,3	44	30	0,6	0,3	9	7
Various Zones of Sary-Bulak Massif									
Center	4	0,2	0,6	5	16	0,1	0,3	3	8
Periphery	12	1,2	1,2	20	27	0,3	0,3	5	7
Endo-contact	8	5,0	1,6	61	38	1,8	0,6	22	14

where $\sigma = \pm\sqrt{\frac{\Sigma x^2}{n-1}}$; = a mean quadratic ratio; $v = \frac{\sigma \cdot 100}{c}$ = coefficient of variation;

$m = \pm\frac{\sigma}{\sqrt{n}}$ = error in determination of average content; p = the same error expressed in

percentage = $\pm\frac{m \cdot 100}{c}$; c = an arithmetical mean; x^2 = the square of deviation of an individual analysis from the mean value; n = number of samples.

NOTE: Comma represents decimal point.

been rather uniformly altered by autometamorphic and postmagmatic processes such as potassic metasomatism, fluoritization, and chloritization of biotite. Contacts are injected, discordant, with dike-like apophysas and granitization of rock adjacent to the contact.

Table 2

Zones	$n \cdot 10^{-4}$ % U	$n \cdot 10^{-3}$ % Th	$\frac{Th}{U}$	No. of samples
Central	11,0	3,9	3,6	20
Peripheral	13,9	3,2	2,3	40
Endo-contact	16,9	2,6	1,5	40
Near-contact	17,9	2,4	1,3	50
Exo-contact	26,4	1,5	0,6	40
Granitization	15,2	1,4	0,9	40
Hornfelsic	7,0	1,7	2,4	50
Distant from the massif	5,0	1,9	3,8	50
Fluorite veins	10,6	0,6	0,6	8
Sahlbands of fluorite veins	21,4	1,5	0,7	8

NOTE: Comma represents decimal point.

Accessory minerals present in the granites are: zircon, apatite, hematite, ilmenite, titanite, and thorite; secondary minerals are fluorite, chlorite, muscovite, epidote, albite, pyrite and ferric hydroxides.

Distribution of uranium and thorium in different zones of a massif is given in Table 2.

As demonstrated in Table 2, concentration of uranium in granite increases from the central part of the massif toward its periphery. Uranium has penetrated into all the host rocks within the zone of granitization and attained the maximum content near the exo-contact. Uranium enrichment of granite occurred in several stages and resulted in four distinct generations of accessory zircon and a sharply varying uranium content [8]. One of the more significant granite enrichments in uranium was associated with fluorite mineralization. Also, a connection should be noted between uranium enrichment and chloritization.

Distribution of thorium is fairly uniform in the granites; and the thorium has not migrated into enclosing rocks.

2) Alabash Intrusive

This is a small single phase intrusive of alaskite granite of Caledonian age and fissure type similar to the Dzhety-Oguz granites. Granites of this intrusive have crystallized out fairly fast. Postmagmatic processes are revealed only in places at northeastern contacts in zones of late tectonic movements. The total content of uranium and thorium is smaller in these granites than in those of Dzhety-Oguz.

Near contacts, uranium is distributed in accordance with contact types (Table 3).

We have distinguished three types of contact: 1) "cold" with hornfels developed in zones of major dislocations, 2) a weak granitization at contacts with more permeable gabbroc 3) tectonic contact with limestones affected by postmagmatic hydrothermal alteration.

Thus, considerable uranium enrichment is present only on contacts of the third type where it is due to some later, superimposed postmagmatic process not related to the emplacement of magma itself. A small amount of uranium, but not thorium, was evidently added also during granitization.

3) Sary-Bulak Intrusive

This intrusive is composed of the same medium-grained alaskite granite of Caledonian age as the intrusives previously mentioned. It is characterized by a feeble greissenitization of medium-grained granites near their contacts and the absence of greissenitization on borders of fine-grained granites.

Accessory minerals are comparatively few

Table 3

Zones	$n \cdot 10^{-4}$ % U	$n \cdot 10^{-3}$ % Th	$\frac{Th}{U}$	No. of samples
Central	4,4	2,2	5,0	10
Peripheral	5,3	1,6	3,0	20
"Cold" contact	4,7	1,3	2,8	10
Granitized contact	6,5	0,3	0,5	10
Postmagmatic altered contact	16,2	1,5	0,9	10
Enclosing rocks	2,4	0,7	2,9	20

in these granites. Apatite, ilmenite, and fluorite are present in places; zircon and thorite are rare. A simplified zonal distribution of uranium and thorium is given in Table 4.

In this particular case, uranium content was increased in border portions of granites and migrated into adjacent rocks. Fine-grained granites occurring near contacts are not covered by this generalization. This exception is apparently due to the fact that this last-mentioned variety of granite represents a rapidly recrystallized magma. During subsequent developments in the crystallized intrusive, fine-grained granites were less permeable to percolating postmagmatic solutions which carried additional uranium.

4) Kerege-Tash Intrusive

This is a small greissentized stock of Caledonian alaskite granite. Greissenitization consisted of feeble silicification and introduction of abundant fluorite.

In this case, a considerable quantity of uranium has been added during greissenitization while thorium has become partly redistributed and perhaps removed. This view is supported by analyses (Table 5).

5) Northern Terskey Intrusive

We have provisionally grouped a number of large outcrops of Caledonian alaskite granite under this name; they are located in northern foothills of the Terskey Ala-Tau Range and west of the Bereskaun River. Individual exposures are commonly separated by erosion and alluvium; their contacts are seldom observed but obviously these massifs should represent the same, deeply eroded Caledonian alaskite granite.

These exposures of granite display no appreciable postmagmatic alteration. Distribution of uranium and thorium is relatively

Table 4

Zones	$n \cdot 10^{-4}$ % U	$n \cdot 10^{-3}$ % Th	$\frac{Th}{U}$	No. of samples
Central	3,8	4,0	10,5	40
Peripheral	6,3	4,4	7,0	60
Endo-contact of medium-grained granites	12,0	3,0	2,5	40
Endo-contact of fine-grained granites	5,6	4,5	8,0	20
Exo-contact	8,8	1,1	1,2	80
Near the massif	7,4	1,6	2,2	60
Distant from the massif	3,7	1,2	3,3	40

NOTE: Comma represents decimal point.

Table 5

Zones and Rocks	$n \cdot 10^{-4}$ % U	$n \cdot 10^{-3}$ % Th	$\frac{Th}{U}$	No. of Samples
Core of stock slightly altered granite	7,4	3,6	4,9	10
Periphery of stock greissenitized granite	11,2	2,8	2,5	10
Contact facies	14,4	3,0	2,1	10

uniform. Only a slight increase in uranium content is observable at the contact with granite porphyries of the first phase. Results of composite samples taken in eight discontinuous areas are given in Table 6.

3. COMPARISON OF THE MASSIFS

It is interesting to compare the brief descriptions of five different intrusions of Caledonian alaskite granite in the Terskey Ala-Tau Range. Distributions of uranium and thorium in these massifs are shown in Figure 1, numbers in the figure corresponding to descriptions in the text. An idealized scheme of erosional surfaces of the investigated intrusives is shown in Figure 2. By calculating average uranium and thorium contents for each erosional surface and adjusting these values in proportion to visible areas we have obtained the data presented in Table 7.

Space does not permit us to comment in detail on the results obtained nor to consider at length individual examples. This has been done in part in some of our earlier papers which dealt with individual massifs and special questions [3, 4, 7, and 8]. We will limit ourselves, therefore, to a brief summary of deductions that follow from this investigation and from some of those earlier papers cited above.

DEDUCTIONS

1. Uranium and thorium are irregularly distributed in granitic massifs. The coefficients of variation of their contents in individual massifs studied in Tyan'-Shan' are 30 to 45 per cent for uranium and 30 to 35 per cent for thorium. In different zones of the same massif, the coefficient of uranium content fluctuates between 5 and 60 per cent and that of thorium between 15 and 40 per cent.

2. To establish rationality in distribution of uranium and thorium within different zones of the same massif or to compare different intrusions single samples are inadequate. It is best to collect composite grab samples over the entire massif or over any of its zones. The necessary number of such samples is determined from the coefficient of content variation and adjusted for the desired precision of sampling.

3. Granites of the Terskey Ala-Tau, hardly at all weathered, are practically in radioactive equilibrium. Radiochemical analysis could be used to determine their uranium and thorium contents.

Table 6

Zones	$n \cdot 10^{-4}$ % U	$n \cdot 10^{-3}$ % Th	$\frac{Th}{U}$	No. of Samples
Average of central parts of the massif	5,6	2,5	4,5	80
Contact zone	8,6	2,2	2,6	20

NOTE: Comma represents decimal point.

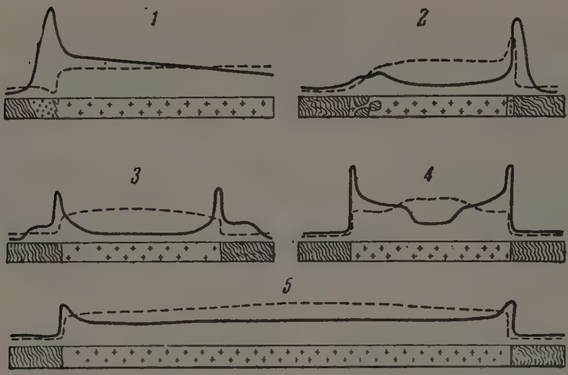

FIGURE 1. Uranium and Thorium Distribution in Different Intrusives.

Solid lines -- uranium; broken lines -- thorium.

4. Zoning is observed, as a rule, in distribution of uranium within granitic massifs. Uranium content usually rises from the center towards the periphery of the massif, raching the maximum in the contact zone. During granitization and the post-magmatic stage, uranium penetrated into enclosing rocks forming aureoles of concentration near the contact commeasurable with concentrations in the granite. No such regularities were observed in intrusives of the fissure type that have crystallized quickly. These aureoles are less pronounced where batholiths were deeply dissected. Consequently, different granitic massifs, belonging to the same phase of intrusive activity, may display different radioactivity in proportion to depth of erosion and intensity of autometamorphic and postmagmatic processes. This must be taken into account when calculating different Clarkes needed for correlation of "related" magmas and for comparison of granites of different "cycles" and "phases".

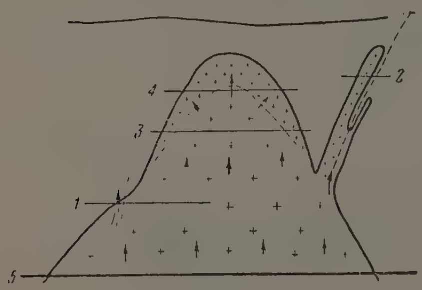

FIGURE 2. An idealized scheme of erosional surfaces of the intrusives studied.

Short arrows indicate direction of movement of percolating fluids; long arrows, direction of postmagmatic solutions.

5. Thorium is distributed less regularly within granitic massifs. It is seldom concentrated in near-contact zones and may even be depressed there. As a rule, it does not migrate into the enclosing rocks.

6. In all cases considered, thorium migrated almost exclusively during the magmatic stage proper during the emplacement of the intrusive. A small addition and redistribution took place during the early acidic stage — up to and including the period of greissenitization. Uranium, on the other hand, was highly mobile during the emplacement of the pluton. Its increase and redistribution were long and discontinuous processes. In addition to being an initial component of the magma, it migrated in percolating solutions during the autometamorphic stage and was redistributed by postmagmatic solutions of different temperatures.

Thus, several generations of accessory minerals with variable uranium content are cometimes observed in granites, minerals of later generations commonly being more radioactive. Among thorium minerals of later generations, replacement of allanite and monaazite by thorite has been noted in places.

Table 7

Massifs	$n \cdot 10^{-4}$ % U	$n \cdot 10^{-3}$ % Th	$\frac{Th}{U}$	Number of Samples
Dzhety-Oguz	12,0	3,5	2,9	4
Alabash	5,0	2,0	4,0	15
Sary-Bulak	6,2	4,0	6,4	15
Karege-Tash	10,5	3,2	3,0	1
North-Terskey	5,3	2,2	4,2	100
Average on all massifs	7,8	3,0	3,8	—
The same average adjusted to visible area of erosional surfaces	5,6	2,5	4,5	—

NOTE: Comma represents decimal point.

7. The ratios of thorium to uranium and coefficients, "v", of their contents are quantitative expressions of differences in their mobility and their ability to disperse. The thorium-uranium ratio is relatively lower for contact rocks and for rocks altered by postmagmatic processes while v_U is greater than v_{Th}. For slightly altered granite and for central portions of massifs v_{Th} is greater than v_U and the ratio Th/U is considerably higher. An explanation for this evidently lies in the fact that uranium was dispersed more evenly through rock forming minerals during primary crystallization and that uranium was more mobile than thorium during postmagmatic processes.

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ALTERATION PROCESSES IN THE VOLCANIC ROCKS OF THE TRANSCARPATHES[1]

by

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Within the limits of the hypersthene-andesite dome on the western slopes of the Black Mountain (Transcarpathes), we encountered an interesting type of rock alteration characterized by the formation of "spheres" composed of yellowish green clay-like material localized in comparatively unaltered hypersthene andesite. The diameter of the spheres ranges between 5 and 30 centimeters. At times they are quite numerous: for example, in one part of the dome, up to 15 "spheres" 5 to 30 centimeters in diameter could be counted over a surface four square meters in area. It is interesting to note that the rock's weathering process is such, that a comparatively good preservation of femic minerals may already be observed in the field. In places, a linear distribution of a series of similar "spheres" could be observed, creating the impression of threading along one of the cracks. The friable material of such "spheres" is often either removed from the containing formation, or falls out easily by mere contact. At the same time, geometrically regular spherical and ellipsoidal cavities are formed, and they may be commonly observed within the limits of the dome.

Let us briefly examine the characteristics of the material constituting the "spheres", and those of the hypersthene-andesite rocks containing them.

The described hypersthene-andesites differ little from the similar Trans-Carpathian rocks whose characteristics are given by V.S. Sobolev and others [7]. Therefore, let us retain the essential.

Aside from the strikingly predominant hypersthene among the dark-colored phenocrysts present in the rock, olivine, monoclinic pyroxene and hornblende are present, while among alumina-bearing minerals there is plagioclase. As to the matrix, it contains plagioclase, quartz, orthoclase, and in the less weathered areas — obsidian and tridymite. The basic texture of the matrix ranges from hyalopilitic to micropoikilitic.

Hypersthene has a 2V = -60° (from two measurements of the optic axes). $\gamma = 1.730 \pm 0.002$; $\alpha = 1.718 \pm 0.002$ (these and further measurements were made by immersion of uncovered microsections on the Fedorov stage). Hence, their ferruginosity is expressed by 56 to 58 per cent of $FeSiO_3$ [1].

The olivine was mainly preserved in a form of corroded inclusions in the hypersthene, and it appears to be the first product of magma crystallization, which indeed explains its low ferruginosity (35 to 40 per cent Fe_2SiO_4). 2V = -(78° to 79°) was measured by the A.N. Zavaritskiy method [3]: $\alpha' = 1.702$.

The monoclinic pyroxene has 2V = + 54°, $c\gamma$ 44°. Hence, its ferruginosity is about 60 per cent of the hedenbergite molecule [1].

The fallow greenish hornblende has opacitic edges. $\gamma = 1.682 + 0.002$, $\beta = 1.663 + 0.002$, 2V = -(79° to 81°) from two optic axis determinations; $c\gamma$ 8-9°.

The plagioclase was repeatedly measured by the Fedorov method and in the same crystal (in uncovered thin section) by immersion. Example: $B\gamma = 29$, $B\beta = 62.5$, $B\alpha = 80.5$ compound 50 per cent An; $B\perp(010)\gamma = 1.559 \pm 0.001$, $\alpha = 1.552 \pm 0.001$, i.e., compound 44 per cent An. Since such departures for volcanic rock plagioclase are observed everywhere in Trans-Carpathia, we reach the conclusion that the plagioclase possesses a high temperature orientation of the optical indicatrix.

The plagioclase of the matrix is composed of 32 to 56 per cent An (maximal angles $c\beta$ in the zone $\perp(010)$ = 15° to 25°), and the obsidian has a 1.524 ± 0.002 index of refraction, which corresponds approximately to a 62 per cent SiO_2 content.

---

[1] O protessakh izmeneniya v Vulkanicheskikh porodakh Zakarpat'ya.

The tridymite is observed in a form of scarce wedge-shaped crystals and is usually found in the interstices.

Let us now examine the altered form of the "spheres". Let us note, by way of anticipation, that these forms represent the residue of materials of homogenous inclusions in the dome-containing rocks.

The buried structure of the rock is porphyritic (rhyolitic, to be more precise, with a small amount of matrix).

Only greenish clayey pseudomorphs remain of the bulk of plagioclase crystals. Coarse tridymite crystals (0.25 to 1 millimeter in length) are frequent. Finally, the dark-colored minerals of the rock, the monoclinic pyroxene and hypersthene, are comparatively well preserved (disregarding the hydrous iron oxide along the edges of the grains). As to the obsidian, it is entirely replaced by a secondary clayish product.

The monoclinic pyroxene has 2V = 53° to 54°), $c\gamma$ = 44 (the measurement made by D.S. Korshinskiy's method of 1928). About 60 per cent of hedenbergite molecule [1] is included in its composition.

The hypersthene has 2V = - (60° to 61°).

The tridymite usually forms elongated and at times twinned tablets, for example $B\gamma = 20$, $B\beta = 88$, $B\alpha = 70$. B coincides with the perpendicular to the double seam $\beta = 1.478 \pm 0.002$, $\alpha = 1.477 \pm 0.002$, 2V = + 82 (along two optic axes). The indices of refraction were measured in thin sections immersed on the Fedorov stage. At times, tridymite changes into something like a plagioclase pseudomorph (Figs. 1 and 1A). It is possible to discern under greater microscope magnification,

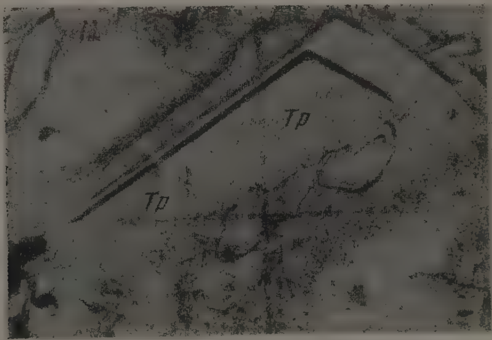

FIGURE 1. Tridymite pseudomorphs after plagioclase.

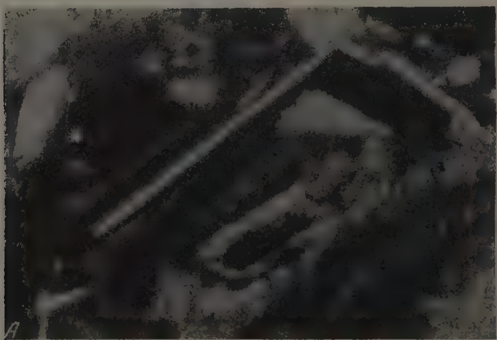

FIGURE 1A. Same and general aspect of the transformed rock.

Thin section 241-B. Magnified 108X, nicols parallel.

minute isometric gaseous, and essentially gaseous inclusions in the tridymite, but no liquid inclusions are formed.

Not less than 80 per cent of the weathered rock's matrix are composed of a light green secondary mineral of aggregate construction. The finest, monolithically distinguishable isometric particles are 0.002 to 0.003 millimeters in diameter, and of a dark gray interference color. The mineral is non-uniform, certain of its angular areas are not isotropic, and the surrounding mineral with an aggregate construction has zoned edges of the same mineral. The oriented disposition of crystals is absent, the average refractive index, measured under immersion, is (1.530 to 1.532) ± 0.002.

The fact that the angular isotropic areas of the green mineral represent plugged interstices is not excluded.

The differential curve of the altered rock is represented on Figure 2. Comparing it with the curves of the halloysite group of minerals [2], our curve resembles that of ferrihalloysite, and also the monomineral ferrihalloysite of the western slope of Black Mountain rocks. A similar curve is drawn by Ye. F. Maleyev for the red ferrihalloysite developed in the Baranovsk volcano of the Primor'ye (maritime region) [6].

The curve of the altered rock dehydration described above is presented on Figure 3. The general loss of water is 13.3 per cent, but if we take into account the fact that the clayey mineral constitutes nearly 80 per cent of the total mass of the material composing the "spheres", its water content would be about 16 per cent. The general configuration of that curve resembles that of ferrihalloysite dehydration as presented by I. I. Gorbunov [2]. The details of these curves are already distinct because the points of our curve are disposed at 20 degrees intervals. It is interesting to compare Figures 2 and 3; it is clearly visible that the endothermic effects of Figure 2 are combined with the loss of water in the same temperature intervals (Figure 3).

Finally, observations by means of an electron microscope uphold the determination of the mineral as being ferrihalloysite (Fig. 4) and show a certain halloysite admixture (Fig. 5).

Let us also note that the observations in thin sections show too, that the ferrihalloysite "consumes" here not only the obsidian, but also the plagioclase, and, in part (along cracks), the dark-colored minerals and the tridymite.

It must be stated that in the Trans-Carpathian volcanic rocks secondary products of the ferrihalloysite (halloysite) type were more than once observed within glomeroporphyric accumulations, where they form angular sectors in the obsidian.

As shown above, in the present case the ferrihalloysite is being developed at the expense of the material composing the homogenous inclusions. The latter precisely produce "spheres" of clayey material within the

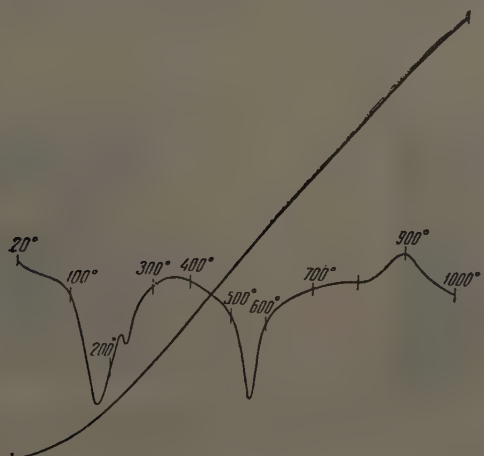

FIGURE 2. Differential curve of the weathered rock heating. Sample 271-B.

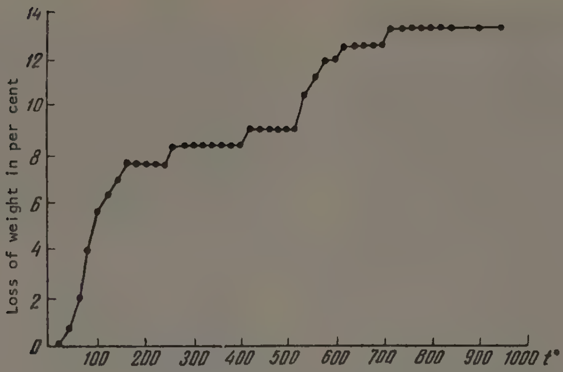

FIGURE 3. Curve of the weathered rock dehydration. Sample 271-B.

hypersthene andesite. As shown by V.S. Sobolev [7], the presence of homogenous inclusions, and also their abundance, "are generally characteristic of hypersthene andesites." From the comparison of optical properties and ferruginosity of dark-colored minerals in the hypersthene andesite containing them, and in the spherical homogenous inclusions, it follows that both are products of the same magma crystallization, and, essentially, the difference between them consists only in the degree of recrystallization of one or the other magmatic material.

Inasmuch as no ferrihalloysite (halloysite) is found in the containing hypersthene andesite, a question arises, under what process was the ferrihalloysite found in the weathered homogenous inclusions, formed?

Let us recall that the transformation of the material composing the homogenous inclusions began with the increased growth of tridymite crystals, forming here and there pseudomorphs in the plagioclase, and also developing within the obsidian. It is natural to assume that the process took place under sufficiently high temperatures. The formation of the ferrihalloysite "consuming" the plagioclases, the obsidian and in part, dark-colored minerals and also the tridymite, began much later.

It seemed to us that under such conditions, only the behavior of a series of elements (and more particularly of rare ones), may provide the answer to what the origin of ferrihalloysite really is, i.e., hypergene (supergene) or hydrothermal (postmagmatic).

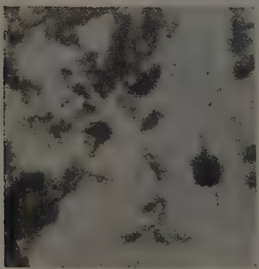

FIGURE 4. Ferrihalloysite of the weathered rock. Sample 271-B.

Electron microscope, 5800X

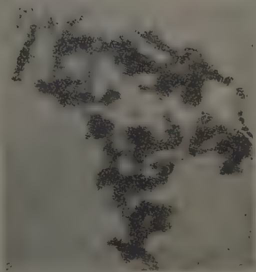

FIGURE 5. Halloysite admixture in the weathered rock. Same sample.

Electron microscope, 6700X

Semi-quantitative spectral analyses of the "spheres" weathered material and of hypersthene andesite bearing them were carried out. (Analyst S.B. Kazakov, Institute of Economic Mineral Deposits Geology, Ukraine SSR Academy of Sciences).

The results of these analyses were compiled on Figure 1, from which it may be seen that some elements ("inactive"), others ("active"), are either eliminated or brought in in the process of tridymite and ferrihalloysite formation.

It is interesting to compare the behavior of a series of rare elements in this process with those facts which A. Ye. Fersman [8] communicates about the corresponding elements in the "hypergenesis" (supergene process). It may be noted (Table 1) that a series of elements which are known to be active in the supergene process (Mn, Sr, V) are more or less inactive in the present case, and, to the contrary, Co, Cr, La, and Sc, are active here, although they are known to be inactive in the supergene process.

Ba, Ca, Cu, behave actively, while Be, Zr, and Ti, are inactive in the supergene process.

The above data indicate, we believe, that the process, instrumental in the appearance of "spheres" essentially composed of ferrihalloysite within comparatively unaltered hypersthene andesites, cannot be recognized as supergene.

It seems to us that at time of tridymite formation, the character of the changing solutions was essentially gaseous (let us recall the substantially gaseous inclusions in the tridymite), while their temperature was not lower than 900°C. Gradually cooling off, the solutions changed into a liquid state, and later entered the formations through the same channels as the essentially gaseous ones. At the same time, the hydrotherms acted in such a way that ferrihalloysite was formed (which assumes that the temperature of solution was not higher than 100°) not only at the expense of plagioclase and obsidian, but also, in particular at the expense of dark-colored minerals and even of tridymite.

Thus, it is hardly possible to doubt the possibility of ferrihalloysite formation by post-magmatic processes. Consequently, it is possible to concur with T.S. Lovering [5], who classified halloysite as being in the group of minerals formed equally by hydrothermal and by weathering processes. However, one problem still remains obscure, and that is, to what extent the ferrihalloysite (halloysite) formed by the hydrothermal process is distributed within the belts of Trans-Carpathian volcanic rocks.

Table 1

Number	Elements	Quantity (in per cent)[b]		Behavior during the process	Migration capability in the hypergene installation after Fersman [8]
		1[a]	2[a]		
1	Ba	α	$\gamma+$	Losses	Active
2	Ca	*	β	"	"
3	Co	–	d	Gains	Little active
4	Cr	–	γ	"	" "
5	Cu	traces	$\gamma+$	"	Active
6	La	"	–	Losses	Inactive
7	Sc	–	γ	Gains	"
8	Na	*	α	Losses	Active
9	Al	*	*	?	"
10	Be	d	d	Inactive	Inactive
11	Fe	*	*	?	Active
12	Mg	*	*	?	"
13	Si	*	*	?	"
14	Mn	β	β	Inactive	"
15	Sr	γ	γ	"	"
16	Ti	α	α	"	Little active
17	V	γ	γ	"	Active
18	Zr	$\gamma+$	$\gamma+$	"	Inactive

[a] 1 means unaltered hypersthene-andesite (sample 271-A)
2 means altered rock composing the "spheres" (sample 271-B)

[b] α — whole (1 to 3 per cent); β — tenths (0.1 to 1.0); γ — hundredths (0.01 to 0.1)
d — thousandths (0.001 to 0.01); * — large amount (> 3 per cent).

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GENESIS OF COMPLEX MINERALIZATION OF THE MANTO TYPE IN KALKAN–ATA DOLOMITE (TASHKENT AREA)[1]

by

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The results of investigation of mineralization localized in dolomitic beds of the Francian Stage in the Kalkan-Ata Mountains are presented in this paper. Investigations carried out by the author, based on lithologic facies analysis of the suite enclosing the mineralization, have indicated a syngenetic and epigenetic origin of this mineralization.

* * * * *

Questions of genesis of sulfide mineralization in sedimentary rocks are among the most complicated and problematic of any in the theory of mineralization. After investigating lead ores of a Francian stratified dolomite in the Kalkan-Ata Mountains and reviewing the concepts of A.G. Betekhtin [4, 5], K.I. Satpayev [13], N.M. Strakhov [14], D.G. Sapozhnikov [12] and others, the author of the present paper has come to the conclusion that they are both syngenetic and epigenetic in origin.

A. METHOD OF INVESTIGATION

The complex mineralization in dolomite of the Kalkan-Ata Mountains is characterized by a number of features characteristic of syngenetic deposits, such as the existence of concordant manto ore bodies, localization of ore in the stratum with abundant Amphipora fossils, a close relationship between recrystallization of enclosing dolomite and recrystallization and enrichment of ore. Thus, we thought it useful to investigate lithologic peculiarities of the mineralized suite.

We have attempted to determine the history of formation of this ore, relating it to the history of geologic evolution in the Kalkan-Ata Mountains. We started by analyzing lithologic facies in order to ascertain the probability of accumulation of syngenetic lead. We have considered: 1) general regional geologic settings which controlled the metallogenic character of the entire Tashkent region, 2) geologic character of the Kalkan-Ata area, 3) structural geology of ore showings and the role of structural, tectonic controls in localization of ore in mantos within dolomite, 4) physical and mechanical properties of the host rocks, i.e., their stratification, fissility and porosity. Textural and structural features of the ore were considered since "structure of the mineral aggregate reveals not only the process of initial crystallization but also conditions under which the mineral aggregate subsequently existed" (A.G. Betekhtin, [4]).

Investigation of the composition of disseminated ores in dolomite was carried out in conjunction with similar studies in other mineralized areas, all belonging to different sequences of Lower, Middle and Upper Devonian sedimentary rocks in the Kalkan-Ata Mountains.

B. A BRIEF MINERALOGIC AND GEOLOGIC DESCRIPTION

The ore showings discussed lie in the Kalkan-Ata Mountains on the northwestern edge of the Kuraminsk Range. The disseminated lead mineralization, which is economically marginal in some small areas, is limited to one of the dolomitic units in the lower Francian stage of transgressive carbonate laters, D_2 - C_1. These layers, represented at the bottom by basal conglomerate and sandstone, up to 340 meters thick, unconformably overlie an erosional surface of intensely deformed Silurian shale and Lower Devonian pyroclastics into which pre-Zhivet magmas have been intrueded. This Paleozoic section ends with a fairly thin pyroclastic sedimentary suite of presumably lower Permian age.

[1]O genezise polimetallicheskogo orudeneniya plastovogo tipa v dolomitakh Kalkan-Ata (Pritashkentskiy rayon).

The most common rock type of the intrusives is granodiorite porphyry of pre-Zhivet age. Variscan intrusives, cutting sediments of D_2 - C_1, are represented by small stocks of quartz diorite, syenite-diorite and basic dikes.

The mineralized layer is traceable in the dolomite over a distance of more than 10 kilometers. Galena dissemination is restricted to strata of black "spotted" dolomite intercalated either by marl (in the area of Taldy-Say) or other dolomitic rocks containing considerable clastics (in the area of Kuru-Say). The overall thickness of the mineralized suite in carbonate rocks ranges from 12 meters in the northern to 40 meters in the southern part of the mountains.

Ores form small mantos, 100 to 120 meters long and 1 to 1.5 meters thick. Ore minerals are distributed irregularly within the dolomitic stratum, and transitions to host rocks are gradual, therefore, the outlines of ore bodies may be determined only by actual sampling. Lead content is 10 or even more times greater than zinc content and reaches 1.0 per cent. Distribution of areas with higher concentrations of sulfides does not show any relation to changes in attitudes of the dolomitic stratum. All faulting of the mineralized horizon was post-mineralization. Neither does the manto mineralization in dolomite show any relationship to Variscan faulting of the first and second order.

The ore composition is not mineralogically complex, galena and, locally, chalcopyrite predominating. Pyrite and sphalerite are intimately associated with galena and form minute inclusions in grains of galena discernible under the microscope. Gangue minerals are dolomite, quartz and less commonly — calcite and barite. The most common is recrystallized dolomite which invariably accompanies mineralization.

Disseminated ores confined to the same dolomitic stratum predominate, the size of individual particles ranging from a few hundredths of one millimeter to one centimeter. Stringer-type mineralization is much less common. Ore bodies with a brecciated texture occur only in places.

Among predominant euhedral textures, cryptocrystalline, spherulitic (gelliform) and also skeletal crystalline (dolomite rhombohedra), poikilitic (galena inclusions in recrystallized idiomorphic grains of dolomite) and others suggest recrystallization after the ore had solidified.

C. FEATURES OF MINERAL PARAGENESIS

1. The mineralized dolomite is characterized by well-defined geochemical and lithologic features, being a facies originating in stagnant basins whose muds were contaminated with hydrogen sulfide — the most appropriate condition for the formation of sulfides. The Amphipora fauna testifies to reducing conditions and abundant hydrogen sulfide in those carbonaceous muds. Formation of dolomite was a link in the chain of events that began on a coastal plain which periodically was invaded by seas and was gradually transformed into an open basin [1]. Inasmuch as mineralized dolomite differs from barren dolomite by lack of admixed clastics, by higher content of organic carbon and by presence of disseminated authigenic pyrite, we believe that dolomitization took place in still marine basins cut off from a supply of terrigenous material. Those portions of marine basins in which dolomite formed were obviously troughs elongated parallel to shorelines. These troughs occurred between sandbars on shallow shelves, far enough from shores not to receive any terrigenous material brought in by rivers.

Alkalinity was rising in such areas due to decomposition of organic matter while evaporation of shallow marine waters steadily increased concentrations of dissolved salts — including MgO. The presence of Amphipora fossils, however, suggests that concentrations could not have been increased appreciably and that salinity remained nearly normal. Lack of authigenic magnesite and sulfate in paragenesis with dolomite supports such a view.

Under these conditions of increased alkalinity and MgO concentration dolomite could form (we agree with N.M. Strakhov [14]) only in a syngenetic-diagenetic way. Magnesium carbonate could have been added to sediments either as one of its hydrates or as dolomite. Various hydrates were homogenized in the highly alkaline medium and in the presence of CO_2 evolving from decaying organic matter, and combined with calcareous matter of certain muds to form dolomite.

The facies so described closely resembles gray mud basin facies of D.V. Nalivkin [8]. According to Nalivkin, such facies are characterized by variable ratios of the following three components: organic matter, silica and carbonates.

Thus, it may be accepted that the mineralized dolomite represent a facies originating in stagnant basins whose muds were contaminated with hydrogen sulfide. High organic content, associated with definitely authigenic iron sulfides suggests not only syngenetic formation of iron sulfide in such dolomite but also a syngenetic character for the entire paragenetic complex of ore minerals of this facies — pyrite, sphalerite, chalcopyrite, galena, as well as the gangue minerals, dolomite and quartz.

Analyzing the distribution of Fe, Mn and

lesser elements in rocks making up the mineralized layer, we have come to the conclusion that the bulk of lead, iron and copper was delivered to the places of formation of mineralized dolomite in the form of soluble salts [2, 3].

Mineralization of dolomite may be considered a result of combined chemical precipitation, absorption and biologically selective extraction of certain components from marine solutions and the subsequent diagenetic transformation of these into primary solid phases. These then became trapped in accumulating sediments. Thus, the biogenic factor (development of plankton), partly a result of decreased supply of terrigenous material, could have easily controlled accumulation of organic matter and silica in these muds. Heavy metals could be delivered in several ways. They could have been dragged down during flocculation of dissolved iron and its precipitation as hydrogoethite; they could have been absorbed either directly by dolomite itself [11, 20] or by the organic matter contained in muds. During diagenesis under reducing conditions, heavy metals and trivalent iron and manganese would become resorbed and transferred to solution in mud. As the pH and Eh of the mud medium became adequate due to increased CO_2 and H_2S content, these metals, liberated by decomposing organic matter, were again precipitated but now in sulfide form. At a later diagenetic stage redistribution, recrystallization of mineral substances, and metasomatic replacement of organic matter by galena took place.

2. The mineralized dolomite is analogous to other dolomitic strata of D_{2+3} measures in physical and mechanical properties, such as stratification, fissility and porosity and differs only in genetic peculiarities proper to their facies.

3. Manto is the form of ore deposition. Distribution of mineralization was not affected by the structural type folding, and intensely mineralized areas show considerable structural variations. However, mineralization has been restricted to the Amphipora zone and this fact constitutes a good guide in prospecting.

4. The disseminated type of mineralization generally predominates within the limits of the producing layer.

5. Galena spots and stringers in dolomite do not show any physical or genetic relationship to mineralization in fissures. In other words, rock shattering was not the factor controlling mineralization in these dolomites.

6. There is no genetic connection between disseminated ores in dolomite and ores of the fissure-filling type, the latter being attributed to injection of ore solutions. This conclusion is based on the following geologic and geochemical criteria: a) no increase in lead content has been noted on contacts of mineralized dolomite with quartz-barite veins; b) the vein minerals barite and dolomitic calcite are contaminated with lead, zinc and silver only where mineralized dolomite is cut by such veins. Where these veins cross barren strata these three elements are absent in the vein minerals. With the exception of lead in barite, these elements are probably in solid solution.

The above facts testify to the absence of any physical or genetic relationship between ore minerals disseminated in the dolomite and mineral veins. Solutions that deposited quartz, barite and dolomitic calcite obviously became enriched in such metallic elements as lead, silver, and zinc, during interaction with the enclosing dolomite.

Hydrothermal veins cutting sedimentary layers D_{2+3} are younger than the disseminated ore in the dolomite.

Assuming that hypogene hydrothermal solutions were propagated along microcapillaries and submicroscopic flaws, such solutions should have been blocked in their rise by marl below the actually mineralized dolomite and should have deposited their metallic loads in some lower dolomite layer covered by the marl. However, this has not been observed notwithstanding the fact that these lower-lying dolomites, different as they are in facies, possessed the same physical and mechanical properties, i.e., excessive porosity and fissility, and consequently should have been just as susceptible to epigenetic mineralization.

7. A distinctive feature of lead ores in the dolomite is their high content of such trace elements as As, Sb, Ag and absence of other elements like Be, Ga, Sn, or Bi. These latter elements are characteristic trace elements in galena of hydrothermal deposits known to exist in the Kalkan-Ata Mountains and for that matter in the entire Tashkent region. Ore composition in the Kalkan-Ata dolomite is similar to that of ore deposits of Sumsar, and southern Kirghiziya, which lie in a Zhivet dolomitic sequence.

8. In mineralized dolomite, chalcopyrite contains Pb, Zn, Ag and Sb as trace elements. None of these trace elements has been found in chalcopyrite of quartz-barite veins traversing basal sandstone.

The following structural and textural features of dolomitic ores aid us in understanding their origin: a) galena inclusions are

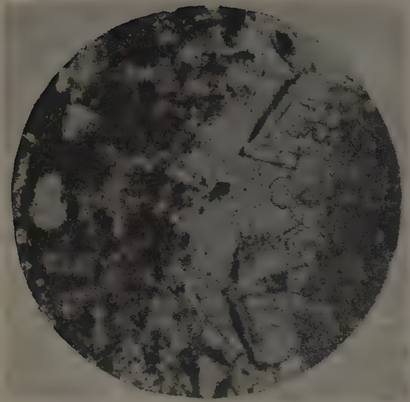

FIGURE 1. A gradual transition from dark, fine-grained dolomitic rock to coarsely crystalline dolomite. Note galena inclusions (black).

23X, parallel light.

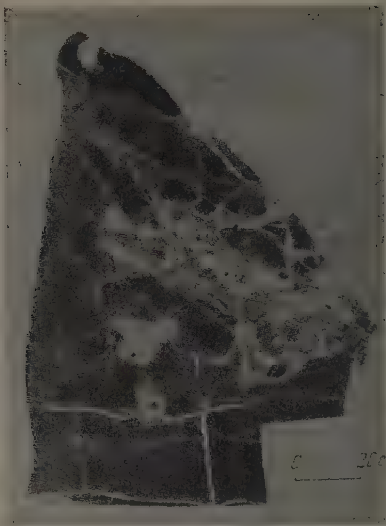

FIGURE 2. Disseminated galena ore. Galena inclusions appear light against the background of recrystallized dolomite.

3/4X natural size.

invariably associated with coarsely crystalline dolomite which has evidently recrystallized from fine-grained dolomitic material (Fig. 1); b) recrystallization is limited to the vicinity of galena inclusions (Fig. 2) in mineralized dolomite and recrystallized dolomite which has not been invaded by ore, suggesting contemporaneity of ore emplacement and dolomite recrystallization; c) a total absence of intergrowths between different ore minerals indicates no fissure control in formation of ore; d) there is weakly manifested metasomatic replacement of gangue minerals by ore minerals; e) the shape of cavities resembles geode-like concretions formed about central sulfide minerals, concretion walls being composed of idiomorphic grains of quartz and dolomite (Fig. 3).

Analogous formations but without sulfides occur in non-mineralized dolomite (Fig. 4) and are considered by us to be the results of diagenetic transformation within the rock. Galena-filled cavities, surrounded by coarse idiomorphic crystals of dolomite probably originated during recrystallization of dolomite which was accompanied by separation and segregation of syngenetic accumulations of quartz, barite and sulfides. This conclusion is based on the following facts: small, clearly syngenetic quartz grains and pulverized pyrite occur in a fine-grained dolomitic mass which changes gradually into coarsely-crystalline dolomite in the vicinity of ore inclusions. Quartz and pyrite are also grouped about galena inclusions in coarsely crystalline dolomite but, similar to dolomite, are coarser grained in this case. It is possible that both quartz and pyrite were localized and were segregated similar to dolomite during crystallization.

Indisputable presence of recrystallization complicates the determination of the age of various minerals. The observable indications of corrosion and replacement should not be interpreted as due entirely to replacement of carbonates with sulfides because individuals, crystallizing in solid media, may develop crystallites of "skeletal growth" and occlude particles of adjacent minerals. Therefore, crystallites of "skeletal growth" (Fig. 5) should be regarded as having formed later than galena; fine disseminations of galena in dolomite (Figs. 3 and 6) should be regarded as older than dolomite. No galena penetrations have been observed in idiomorphic dolomite crystals.

Thus, the age relationship of minerals

filling cavities to minerals which surround such cavities cannot be interpreted when there is evidence of recrystallization in solid media. It is most likely that the coarsening of dolomite grains through recrystallization of a fine-grained matrix and the filling of cavities by galena are nearly contemporaneous processes.

and by the wide development of carbonatites possessing cryptocrystalline structures, and also by indications of hydrothermal activity, suggest that hydrothermal solutions were mainly responsible for the metamorphism. However, the feeble manifestation of hydrothermal activity within these carbonatites and the peculiar geochemical character of

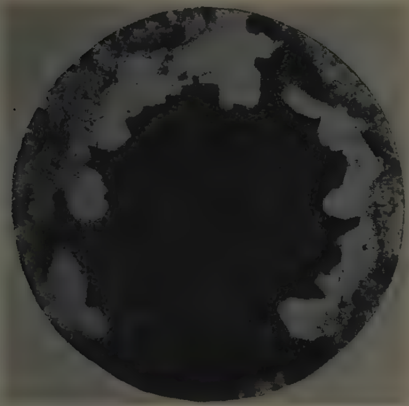

FIGURE 3. A cavity in dolomite, filled with galena (black). Cavity walls are lined with idiomorphic quartz crystals. Note dot-like galena inclusions around larger galena inclusions in quartz and in dolomite.

90X, parallel light.

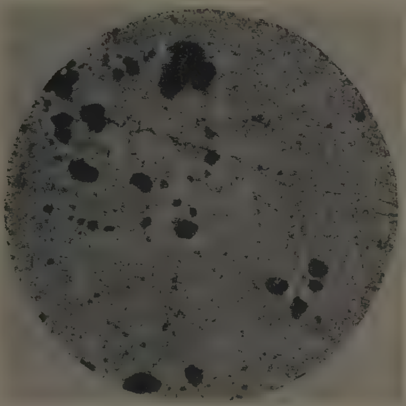

FIGURE 4. An aggregate of carbonatite with a microgranular structure and geodes of recrystallized dolomite (light gray). In association with quartz and ore minerals (black).

30X, parallel light.

The manifest replacement and observable mutual intersections of vein minerals are controlled to a large extent by a later metamorphism of ore-bearing dolomite. Post-mineral recrystallization is also indicated by the granular interior structure of sphalerite twins.

Recrystallization and segregation of mineral substances during diagenesis and subsequent metamorphism undoubtedly occurred in the presence of solutions. This is indicated by the microscopic fillings of quartz and galena which formed at a later stage indicating stringer-like migrations of solutions.

Existence of emulsion-like and other structures suggests that segregation and recrystallization of ore minerals took place at elevated temperatures.

A generally moderate grade of metamorphism of ore-bearing rocks, indicated by lack of dehydration of some rock-forming minerals

the ores precludes any genetic relationship between these ores and the typical ore mineralization of the region. Obviously, hydrothermal solutions that have reworked disseminated ores in dolomite were remnants of hydrothermal mineralizers that had deposited their loads along fault surfaces.

All these facts led the author to conclude that processes of diagenesis, metamorphic recrystallization, and segregation of mineral substances within ore-bearing dolomite were closely interwoven.

The total lack of structural control over localization of ore, feeble alteration of enclosing rocks, absence of any geochemical relationship between this mineralization in dolomite and typical complex hydrothermal mineralization in the region, and, finally, lead contamination of dolomite of certain facies all contradict the theory of hydrothermal origin of disseminated ore in these dolomite manto deposits.

A.I. Tugarinov's data on the isotopic composition of lead from galena of the complex manto ores of the region [16], suggesting a Devonian age, support the theory of syngenetic accumulation of lead sulfides since all hydrothermal deposits of the region belong to a late Paleozoic metallogenic epoch.

Our former views on hydrothermal genesis of lead ores in dolomite of the Kalkan-Ata Mountains are not satisfactory in the light of present knowledge. The paragenesis of specific sulfides (pyrite—chalcopyrite—sphalerite—galena in association with quartz) which I have previously cited as a proof of hydrothermal genesis of these ores in dolomite is actually characteristic of all sedimentary formations. This is exactly the same mineral paragenesis that has been recognized and described by A. Ye. Fersman from Carboniferous strata near the city of Borovichi [17, 18]. An analogous paragenetic complex of sedimentary sulfides has been studied by V.A. Obruchev from Cambrian limestones along the upper Lena River [10]. There can be no doubt as to the sedimentary origin of sulfides of iron, copper, lead and zinc in phosphorites of Podoliya and elsewhere. The clearly epigenetic form of galena segregations in the enclosing rocks and its relatively later age compared to sulfides of other metals is very characteristic of syngenetic mineralization.

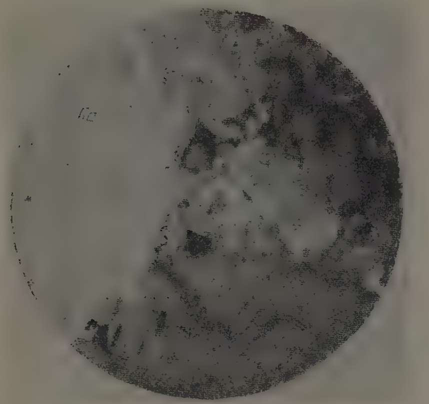

FIGURE 5. A grain of dolomite (black) corroded with galena (white). This structure is considered to be a skeletal dolomite rhombohedron.

45X, reflected light.
Ga = galena, Cer = sericite, Dol = dolomite, Q = quartz.

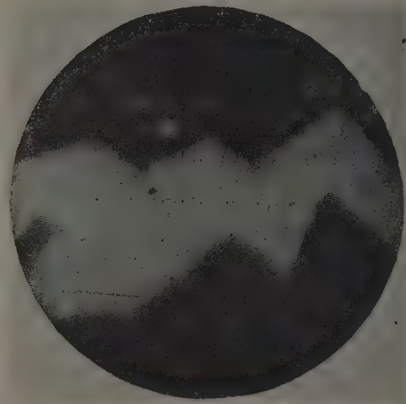

FIGURE 6. Minute inclusions of galena (white) in idiomorphic grains of recrystallized dolomite (black) surrounding galena inclusions (white).

250X, reflected light.

As shown by investigations of N.M. Strakhov [15], N.V. Kirsanov [6], V.P. Florenskiy and N.A. Mikhaylova [19], N.V. Logvinenko [7] and others, recrystallization, redistribution of mineral substances in rocks, segregation of disseminated sulfides into larger crystals and metasomatic replacement of some minerals by others are perfectly common in sedimentary formations. "A number of postulates of the theory of infiltrational metamorphism and the philosophy of differential mobility of components are fully applicable to these processes" [7]. Signs of corrosion (metasomatic replacement) of some minerals by others have been observed by the author in sedimentary rocks not displaying any metamorphic alteration and obviously resulting from some earlier stages of diagenesis.

Presence of specific trace elements (e.g., Cd in sphalerite), which has been cited previously as a proof of hydrothermal origin of lead ores in dolomite, is not reliable because according to investigations of N.V. Kirsanov [6] and others these elements are typical impurities in some minerals, hence their presence sheds no light on the origin of the mineral.

It is hoped that the lack of definitely

formulated views on the source and means of transport of heavy metals under the described conditions will not be held against us. Such theories of mineralization are most complex and problematic and afford no single solution even in the case of endogenic ores which generally have longer histories. This is particularly true of the practical application of such concepts.

We accept as a working hypothesis that the main source of syngenetic lead was in volcanic rocks having spectrographically and polarographically higher clarkes of lead content (in the order of hundredths of one per cent). The identical mineral and chemical composition of pre-Zhivet rocks and of clastic material of sediments D_{2+3} suggests that Lower Devonian volcanic rocks were the main source of minor elements, including lead, for sediments of the Middle and Upper Devonian.

Absorptive processes played the main role in precipitation of lead ore as stated previously. Lead may be absorbed from marine chemical solution by dolomite itself [11, 20] and also by organic matter contained in muds.

A rather intriguing picture is revealed when the possibility of accumulation of syngenetic lead sulfide over large areas of carbonate rocks is considered. The Lower Devonian suite of transgressive carbonate sediments is widely developed in the Chatkalo-Kuraminsk Mountain system and may be traced to the south and southeast into the Bosbu-Tau Mountains lying beyond the limits of the Sumsar region and to the north beyond the Kara-Tau Range.

The ever present lead contamination in certain layers of carbonate rocks led some investigators to think of the lead as syngenetic. Thus, Zhivet dolomites include a lead ore bed in the lower Sumsar region; in Kara-Tau this is a stratum in carbonate rocks of the Famen stage.

At first glance, the difference in age of formation of dolomitic ores in adjacent areas points against their being of the same facies. On further study, the difference in their age of formation not only does not contradict their identity but actually confirms it because consecutive sequence of formation within a transgressive series is to be expected. Therefore, occurrence of ore-bearing dolomite in rocks of the Zhivet stage at Sumsar, on the Francian stage at Kalkan-Ata and of the Famen stage at Kara-Tau should be interpreted as a deposition of an ore bearing facies of dolomite, shifting consecutively in shallow seas. This consecutiveness reflects the extension of the Lower Devonian transgression from south to north in western Tyan'-Shan'.

Such uniform localization of sulfide ores in a single series of sediments over such a large, geologically uniform territory strongly supports the view of syngenetic lead accumulation within the carbonate sediments.

However, certain textural and structural features of lead ores disseminated in dolomite and the well-marked hydrothermal activity throughout the region contradict the hypothesis of a syngenetic-diagenetic origin of these ores [9]. Considering all the characteristics of these ores, we are forced to conclude that these ores underwent several stages of formation. Sulfides of heavy metals, syngenetically accumulating during Francian time were later metamorphosed by hot, possibly hydrothermal solutions.

The idea accepted by us as a working hypothesis is that of syngenetic-epigenetic sufldie mineralization. It does not contradict the observed fact but rather explains them.

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SEDIMENTARY FELDSPATHIC ROCKS OF THE LOWER REDBEDS IN THE NORTH CAUCASUS LOWER PERMIAN DEPOSITS [1]

by

S. D. Levina

Extensive geologic mapping and prospecting surveys conducted in our country employing new techniques and involving many drilling operations have produced new information on geologic profiles over large distances and have resulted in the broadening of geologic science, and in the discovery of new phenomena and processes.

In particular, the recognition of an extrusive sedimentary process, creating specific extrusive sedimentary formations, which differ in composition, structure, and geochemical properties from glacial, humid, and arid forms of sedimentation genesis, appears to constitute a new trend in lithologic science, as very clearly formulated by N.M. Strakhov [9, 10].

Of all chemically formed rocks which are usually associated with underwater volcanism and related thermal activity, some of those considered most typical are siliceous shale, jasper, and silicate. It may be assumed that the rocks formed chemically by the extrusive sedimentary processes which are very diversified, since the incoming silica and alumina (which are considered essential components of postvolcanic products subsequently participating in the sedimentation), generally have a colloidal aspect, are capable of mutual interaction and interaction with the salts dissolved in the waters of the basin with the resulting appearance of silicates and aluminosilicates of zeolithic and feldspathic composition.

Apparently, precisely such a type of rock genesis occurred in the extrusive sedimentary, somewhat variegated Permian formations of the North Caucasus, which in the literature [8] are known as the "Lower Permian redbeds." Here, rock layers, essentially composed of newly formed albite were discovered during our detailed lithologic investigations in that area between 1951 and 1955.

The lower redbeds of the Lower Permian in the North Caucasus whose age was ascertained by V.N. Robinson [8] has a thickness of about 1,200 meters; it is traced by separate outcrops in the "Front Range of the Intermediate zone and of the Southern subzone," between the "Belaya reka" (White River) to the west, and Baksan River to the east. They were deposited by a large-scale sedimentation process, and their lower and upper suites are represented by coarse deposits, relatively speaking (including conglomerate, psephite, sandstone, and carbonate breccias), whereas the middle one is composed of more finely grained rocks, represented in most of the areas, by siltstone and carbonaceous argillite.

Rather thick (250 to 400 meters) mantles of extrusive albitophyre formations occur in the upper part of the lower redbeds. P.I. Lebedev determined their detailed petrographic characteristics [5].

The terrigenous sediments of the lower redbeds of the Lower Permian are enriched in all their textural and compositional variants — from argillite to conglomerate — by carbonate, opal, chalcedony, albite, and in places, by calcium phosphate.

Chemically formed rocks are of clearly subordinate importance; in certain sectors, however, they constitute as much as 5% to 7% of the total thickness, and they form thin layers (0.1 to 0.5 meter) of a few kilometers extent, and are best developed in the middle suite.

Among them are ferrous dolomite (in places similar to ankerite in composition), dolomite, less commonly limestone, dolomitic clayey phosphorite, and feldspathic, essentially albitic rocks, which we called "albitolites."

The described stratum has a rhythmic structure in parts of the section. Chemically formed rocks (among them also the feldspathic ones) show the overlapping of two rhythms.

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[1] **Ob osadochnykh polevoshpatovykh porodakh v otlozheniyakh nizhney krasnotsvetnoy tolshchi nizhney permi na Severnom Kavkaze.**

In the rhythm of the first type (Fig. 1) feldspathic rocks form independent layers; their transgressive and regressive parts have a substantial thickness, and are composed of uniform siltstone or argillite.

In the rhythms of the second type, feldspathic rocks are intimately combined with the ferrous dolomite, commonly strongly enriched by an organic coal-like substance. They seem to form a single layer with the latter (Fig. 2), in which separate types of rocks compose streaks and lenses, commonly included without any distinct stratigraphic continuity. Layers of such type fall into the category of rhythms of relatively small thickness (1 to 5 meters).

The feldspathic rocks not only occupy a determined spot in the rhythms, but are also adapted regularly to those sectors of the redbed formation which are more saturated by chemically formed rocks. In the areas with more intense tectonic dislocations, or with a higher degree of metamorphism, a greater degree of recrystallization of feldspathic rocks occurs but the number of layers in the section is not increased.

By their exterior appearance the feldspathic rocks of the lower redbeds of the Lower Permian look very much like chert or siliceous slate. They are characterized by cryptocrystalline, aphanitic and, less commonly, crystalline and irregularly granular texture; they are very consistent, strong; they have a subconchoidal fracture, which may, in places, be splintery; their color is dark gray, almost black, to meat-red, pinkish and straw-colored, corresponding to the general rock coloring (gray or reddish) of the part in which they are imbedded.

The feldspathic rocks textures are also consistent with those of the containing stratum. They are massive, lamellar, brecciated, with visible lenticular bedding, speckled, oölitic, or spherulitic.

In the varieties of rock, differing by a certain degree of decrystallization, inclusions of flat ferrous dolomitic grains, spherolites and small lenses of an anthraxylon-like organic substances, veinlets and pockets of calcite, quartz, and albite, and also a dissemination of sulfides among which chalcopyrite is encountered, are macroscopically discernible.

The relationship of minerals composing the feldspathic rocks, which determine the rock textures, can only be seen with the help of a microscope.

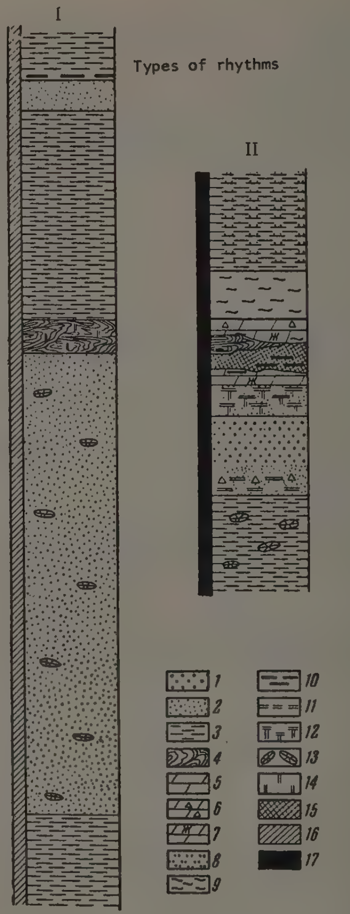


FIGURE 1. Types of rhythms with feldspathic rock layers.

1 -- Coarse siltstone; 2 -- fine siltstone; 3 -- argillite; 4 -- albitolite; 5 -- dolomite; 6 -- dolomite with a brecciated texture; 7 -- ferrous dolomite; 8 -- siltiness; 9 -- clayeyness; 10 -- carbonaceousness; 11 -- micaceousness; 12 -- micaceousness and carbonaceousness simultaneously; 13 -- concretion; 14 -- carbonaceousness; 15 -- phosphorite; 16 -- red-brownish rock color; 17 -- gray color of rocks.

The thick-bedded and thin-bedded, lenticular and speckled textures are the most characteristic of feldspathic rocks. The latter is closely associated with the spherulitic. The lenticular, speckled, and spherulitic textures of feldspathic rocks are developed in those areas which are closer to the zone of the

FIGURE 2. Sketch showing the bedding with lenses of siltstone.

1 -- Micaceous silicon-carbonaceous siltstone; 2 -- ferrous dolomite, in places with albite and phosphate-apatite, 3 -- phosphorite of low albite-carbonaceous content; 4 -- dolomitic albitolite, locally with phosphate-apatite; 5 -- carbon-micaceous-silty argillite; 6 -- coal-like clayey interstratifications.

Main Caucasus Mountain Range, and where the weak regional metamorphism is most apparent (Teberdin-Aksaut region).

The thin-bedded feldspathic rocks are developed in the lower part of the redbeds and they are straw-colored or brownish, in places gray. In the straw-colored variants the bedding is conditioned by a very fine alternation of various shades, differing from one another in their texture — in places, aphanitic; in others, fine-grained. The thicknesses of these fine layers vary to the extent of a few millimeters or even centimeters.

Under the microscope and intransmitted light it is apparent that the rock is colored unevenly in a brownish hue stemming from a finely divided admixture of iron hydroxide. The texture of the rock is pelitic. Its matrix has almost no effect upon polarized light under crossed nicols. It has a 1.5375 ± 0.0015 refractive index which corresponds to that of albite. In some spots a gradual transition occurs into more crystallized sectors which are characterized by flat, reçtangular, and less commonly columnar small crystals, with characteristic polysynthetic twins. As to the matrix, thin streaks, enriched by fine isometric granules and dolomitic grain aggregates, clayey minerals, and sericite may be discerned therein.

One of the structural characteristics, which is well discernible owing to organic matter adherent in them, and usually disposed along the contacts with the streaks, is constituted by sutures (Fig. 3).

The differences in gray color of the thin-bedded feldspathic rocks (Fig. 4) are well expressed. This is explained by the fact, that the organic matter of the rocks is included in layers, thus emphasizing their superimposition. Under the microscope, grayish, brownish, and at times greenish shadings of thin-bedded layers, may be discerned in transmitted light. Their texture is pelitic. With crossed nicols it is easily seen that the thin-bedded texture is modified by the difference of the mineralogic composition of the thinnest layers in which microlitic aggregates of albite, ferrous dolomite, calcium phosphate, and organic matter alternate. The dolomite is more ferrous than that in the straw-colored varieties where the carbonate is closer to pure dolomite in composition. The streaks of organic matter have more commonly a lenticular form. Calcium phosphate is isotropic and in transmitted light has a brownish coloring. Unlike the straw-colored types, a greenish-brownish, commonly isotropic, and in places lightly polarizing ferrous chlorite is rather common in the gray varieties, and is discernible in transmitted light. Its distribution is not subordinate to the bedding, which confirms its formation by diagenesis. In the gray varieties, recrystallization is, in places, clearly apparent.

During the juxtaposition of straw-colored and dark-gray thin-bedded feldspathic rocks, it is seen that the difference of coloring is determined by mineral forms of iron and by the organic admixture, which in turn depend upon their relation to the various facies. The gray, thin-bedded feldspathic rocks belong to "shoestring" or "semishoestring" gulf facies, and straw-colored feldspathic rocks are linked with facies of broad shallow water basins.

The massive and thick-bedded feldspathic rocks are, in their texture, quite analogous to the preceding ones. They are also represented by cryptocrystalline or fine-grained and hornblendelike, but entirely homogenous aggregates. Occurring in one layer, they may be substituted by thin-bedded varieties.

It may be seen in transmitted light under the microscope, that rocks of this type are of a brownish color and have a granular texture (Fig. 5), but under greater magnification it is apparent that the grains are formed by a combination of feldspars of rectangular or square flat contours with polysynthetic

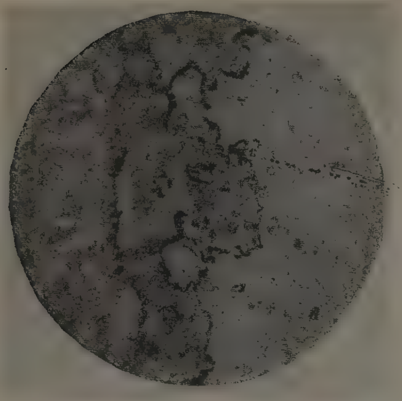


FIGURE 3. Sutural seam in the feldspathic rock.
Magnification 16X; parallel nicols.

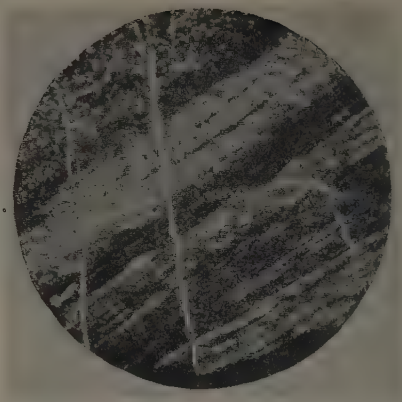


FIGURE 4. Thinly laminated grey feldspathic rock (an.IV, tab. 1).
Magnification 10X; crossed nicols.

twins. Within the grains the feldspar is unaltered, but on the surface it is commonly covered by a thin film of organic substance. Among the accompanying minerals, an insignificant amount of chalcedony, and some dispersed rhombohedrons of ferrous dolomite, partly euhedral, and partly corroded by a feldspathic grained compound, may be noticed. Because of the organic film, the compound's refractive index could not be ascertained.

In the areas composed of ferrous dolomite, microgeodes of albite may be observed (Fig. 6).

The visibly bedded lenticular and speckled feldpathic rocks present very characteristic varieties. It may be seen under the microscope that they are tinted in pink, less commonly, in various shades of gray. Visibly bedded, their lenticular and speckled texture is modified by the separation within the rock of two components — a microlitic compound of albite and one of ferrous dolomite, in places, somewhat "hydrogoethitized." As may be seen from Figure 7, such differences have a visibly bedded-microlenticular or microbreccial texture even under the microscope.

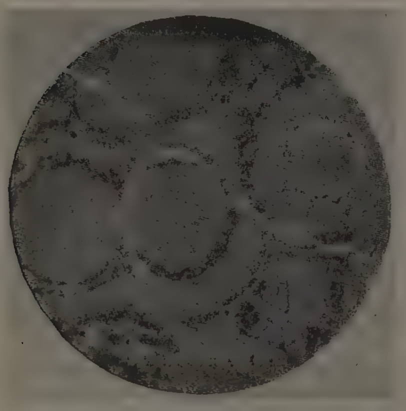


FIGURE 5. Massive grey coal-like feldspathic rock (an.III, tab. 1).
Magnification 112X; parallel nicols.

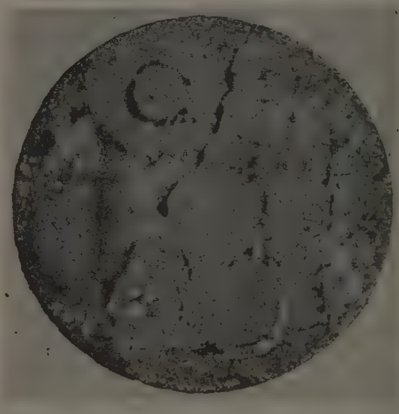


FIGURE 6. Albitic microgeodes in the pelitomorphic albite-dolomitic rock.
Magnification 112X; crossed nicols.

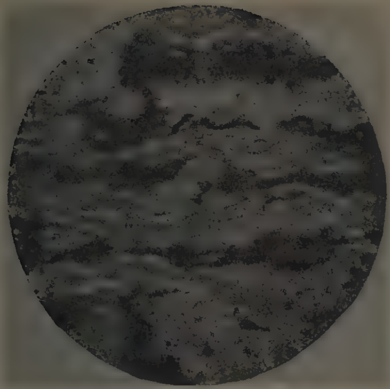


FIGURE 7. The visibly microbedded/ lenticular feldspathic rock (an. II, tab. 1). Clear with crossed nicols -- albitic aggregate (compound).

Magnification 16X.

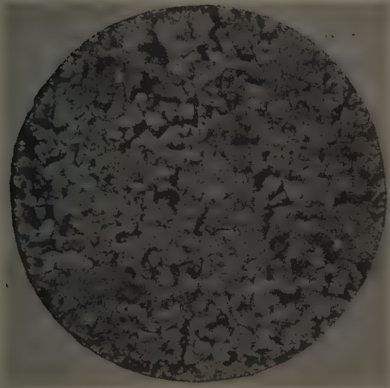
The pelitomorphic dolomite is substituted by a striated albitic compound.

The feldspar is particularly clearly distinguished in rocks with a spherulitic texture, which in comparison with other differences, is less widespread. They form lenses as much as 0.5 meter in thickness, and are of several meters extent; they are interbedded in the middle part of the albitic ferrodolomitic layer (Fig. 2), and have a complex composition: the permanent admixture of ferrous dolomite together with calcium phosphate, clayey and organic substance, is characteristic of them. The feldspar belongs to the albite group and it is included in the spherulites and in the cementing mass. In the rock fracture, perfectly regular spherical surfaces, corresponding to spherulites, are common.

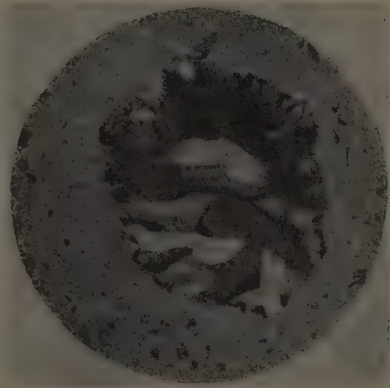
The spherulites of albite composition have a straw color of various shades, in places very pale or nearly white. They are porcelaneous and are distinguished by great density. The cementing mass is characterized by a lesser density and a darker color, conditioned by a larger admixture of ferrous dolomite, by the presence of rather numerous pyrite druses, and also by organic inclusions.

The spherulites are irregularly distributed within the rock, in places close to one another, at times "swimming" in the basaltic cement. There are differences between the uniform internal structure and the concentrically conchoidal bands containing four to five bands. From the center to the periphery the following sequence is noted: the nucleus composed of albite, the concentric band enriched with black organic matter, followed by another albitic sheath, and then another black organically enriched band. The nucleus is less commonly composed of a gray ferrous dolomite, or is substantially enriched with black organic matter.

The size of the spherulites ranges from 1 to 5 millimeters; the thickness of the concentric bands from 1 to 1.5 millimeters. Owing to the greater hardness of albite in comparison with the other feldspathic rock



a



b

FIGURE 8. Concentric spherulites of conchoidal structure (an. VI, tab. 1). Magnification 10X; a -- parallel nicols, b -- crossed nicols. Concentric bands visible; formed by organic matter with ferrous dolomite.

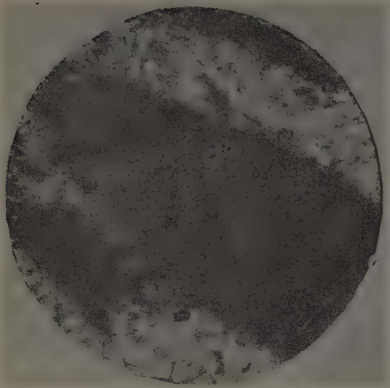


FIGURE 9. Albitic veinlets (an.VII, tab. 1). Magnification 10X; crossed nicols.

constituents, the spherulite's nucleus separates out as a uniform little ball when the rock breaks down. The picking of these balls from the broken down rock under a magnifying glass allows an accumulation of a sufficient quantity of material for chemical analysis and for the determination of specific weight.

It may be observed under the microscope that albite composing the spherulites has a different structure. In the nucleus and in the more central bands, finely crystalline aggregates with an isometrically tabular crystal habit passing into microlitic aggregates are nearly isotropic under crossed nicols.

In the peripheral rings, and more particularly in the outer one, albite is developed within the finely columnar aggregates outgrown on the surface of the preceding ring (band), and it appears unaltered, with a clearly developed twinned structure, and with a maximum extinction angle in the symmetric zone +12, all corresponding to the characteristics of albite-oligoclase. In some of the spherulites the nucleus has a complex composition. An intricate accretion of the isotropic and slightly brownish phosphate may be observed under large magnification (140 times), disclosing numerous inclusions of very fine tabular, rectangular and square granules of fluorine-apatite and also chalcedony and albite. The boundaries of these concentric rings in the spherulite are clearly visible with the naked eye, but microscopic study points to the absence of clear dividing surfaces. The replacement of the mineral composition of the separate rings and the change of color takes place gradually.

In the feldspathic rocks of spherulitic texture, druses and branching albite veinlets are commonly encountered (Fig. 9). They usually do not extend beyond limits of the feldspathic rock layer. Their thickness is not sustained: maximum 5 to 6 centimeters, but more commonly 1 to 2 cm. Their extent does not exceed a few tens of centimeters. In the veinlets among rocks of spherulitic texture, albite with relatively coarsely crystalline columnar aggregates is observed under the microscope. It is unaltered and it commonly appears with polysynthetic twins, and in places as a staggered albite variety.

The determination of optical proprieties of feldspars from the feebly crystalline microlitic rocks described involves significant difficulties and cannot always be successfully achieved. It is hindered by the small size of microlites, by the fine feldspar intergrowth

Table 1

Optic properties of feldspars

Rock	Refractive index	2V	Dispersion of ellip. axes	Extinction	Twins	Specific Weight
Microlitic aggregate of straw color (an. 1, table 2)	1.537±0.001	–	–	–	–	–
Finely grained aggregate of spherulites (an. VI, table 2)	1.531±0.001	+70	r > α	:010-18-19°	Albitic	2.55
Columnar aggregate from veinlets (an. VII, table 2)	γ-1.534-1.537 α-1.525	+72	r > α	:010-14-15°	Albitic	2.58

Table 2
Results of chemical analysis of feldspars from the North Caucasus Permian-Carboniferous Deposits

Constituents	I	II	III	IV	V	VI	VII
SiO_2	73,94	42,21	53,40	52,18	69,08	63,60	67,0
TiO_2	0,19	0,47	Not discovered	0,39	traces	0,13	Not discovered
Al_2O_3	15,53	12,50	16,93	15,57	13,38	18,58	18,91
Fe_2O_3	0,46	1,72	0,03	—	0,16	1,60	0,56
FeO	0,14	3,54	1,43	2,29	0,85	—	—
CaO	0,57	12,54	4,65	5,96	1,88	1,71	1,17
MgO	0,24	3,75	2,25	3,71	0,54	0,67	0,20
MnO	0,02	0,49	0,05	0,14	0,13	0,09	0,04
Na_2O	8,27	5,66	7,99	7,15	7,03	10,70	10,54
K_2O	0,22	0,38	0,64	1,10	0,18	0,37	0,27
P_2O_5	Not determined	2,9	0,02	0,14	0,097	0,092	0,02
CO_2	Same	13,56	6,78	9.40	Not determined	3,03	—
Loss on ignition	0,60	0,16	—	0.80	5,88	Not discovered	1,48
S	0,19	0,07	—	—	—	—	—
C_{org}	—	—	4,99	—	—	—	—
H_2O	0,04	0,04	—	—	0,44	0,04	0,04
	100,41	100,09	99,16	98,83	100,14	100,61	100,23

NOTE: Comma represents decimal point.

Remarks: I — thinly laminated straw colored rock, similar to a siliceous shale (Chilik); II — laminated-lenticular variegated-colored feldspathic rock (Orto-Gidam); III — gray microlitic feldspathic rock (Aksaut); IV — gray thinly laminated albite-dolomitic feldspathic rock; VI — albite from spherulites ("nuclei") (Gidam); VII — albite from veinlets (Gidam).

with other minerals, and more particularly by the accretion of an organic film upon it. The determination of refractive indices in the immersed liquids is made for the microlitic aggregates from the thin-bedded, straw-colored feldspathic rocks and from the recrystallized varieties from spherulites and veinlets. The average refractive index was determined in the microlitic and fine-grained aggregates. The remaining constants were determined on the Fedorov table.

The assembled figures corroborate the fact that the microlitic and recrystallized aggregates of feldspar belong to the albite group.

The fact that the refractive index value of the recrystallized and reprecipitated forms of albite decreases is noteworthy. It may be assumed that its greater value in the microlitic aggregates of albite results from the nature of the inclusions.

The specific weight of the spherulite-originating albite (which was measured by the pycnometric method) resulted in figures lower than the 2.605-2.62 referred to in the paper [2] as being the typomorphic characteristic of the sedimentary feldspars [1, 6]. The specific weight of the veinlet-originating albite is somewhat higher than that of the feldspar originating in spherulites, and this probably may be explained by the liberation of albite from admixtures and inclusions during the subsequent recrystallization.

Various samples for color and structure and texture of feldspathic rocks were analyzed for their chemical composition. In order to compare the composition of minerals with that of rocks, special analyses were made of feldspar from concentric shelly spherulite nuclei and from irregular veinlets.

The results of these analyses are shown in Table 2. They show that a significant amount of such constituents as CO_2 and P_2O_5, and organic matter are included in the Permian-Carboniferous feldspathic rocks of North Caucasus. The quantity of these admixtures varies within broad limits. The relation of chemical analyses to mineral composition as was done in Table 3 taking account of the microscopic data, established that the ferrous dolomite and the chalcedony, whose ratio reaches 20% to 22%, constitute the essential feldspathic rock admixtures. The content of the albitic molecule in the feldspars of the investigated rock samples varies from 85.2% to 96%; that of orthoclase, 1.0% to 8.6%; and that of anorthite, from 1.8% to 9.7% (Table 4). In accordance with the accepted plagioclase classification, this provides the basis for relating them to albite. The orthoclase molecule admixture is a usual thing for albite [2]. But the particularly pure variety of albite, close to the theoretical one (exluding the dolomite admixtures) is represented by the spherulitic nucleus (an. VI, Table 2).

As to the admixture of rare elements in feldspathic rocks, it may be judged from the data of spectrographic analyses (see Table 5).

To the number of elements exceeding the Clark composition by one or even two decades, Mg, Ti, V, Cu,.As, P, Sr, Ba, Co, Zr, Pb, Y, Yb may be related. Such an association is characteristic of sedimentary rocks containing an admixture of organic matter, in part (Sr, Ba, Zr, Pb) — for phosphorites.

The above-presented data concerning the

Table 3

Mineral composition of the investigated samples of feldspathic rocks (using data of chemical analyses)

	I	II	III	IV	V	VI	VII
Albite	75,8	—	66,00	65,55	64,4	90,1	89,08
Orthoclase	1,2	—	3,90	6,60	1,2	2,2	1,11
Anorthite	1,11	—	7,50	4,40	1,4	0,55	3,61
Opal-Chalcedony	20,0	—	2,20	0,40	22,90	—	3,12
Ferrous dolomite	1,1	—	13,30	20,30	5,35	6,8	2,06
Organic matter	—	—	7,00	—	3,55	—	0,60

NOTE: Comma represents decimal point.

Table 4

The relation of Ab, Or, and An molecules
in the samples of feldspathic rocks investigated, expressed in per cent

Molecules	I	II	III	IV	V	VI	VII
Ab Or An	95,6 1,4 2,8	85,2 5,0 9,7	85,2 5,0. 9,7	85,5 8,6 5,8	94,1 1,7 4,2	96,6 2,2 1,8	91,8 1,0 7,0

NOTE: Comma represents decimal point.

condition of deposition, the extent, and the composition of feldspathic rocks from the Lower Permian redbeds of the North Caucasus, confirm their unusualness and leave no doubt as regards their genetic relation to the sedimentary stratum.

This is confirmed by:

1. The constant (permanent) association of feldspathic rocks with chemically formed rocks within the limits of a single layer, namely with the ferrous dolomites and phosphorites, and the existence of gradual transitions between them.

2. The expansion of feldspathic rocks in those parts of the sections which are characteristic of an optimum development of other chemically formed rocks.

3. The same type of rhythmic bedding, lodging the feldspathic rocks in different parts of the Lower Permian redbeds of North Caucasus.

4. The absence of connection between the degree of metamorphism of the redbeds and the number of feldspathic rock layers.

5. The coloring of the feldspathic rocks, which is similar to the color of that part of the redbed section in which they occur.

6. The presence of the thin-bedded variety of feldspathic rocks with interstratifications of microlitic aggregates of feldspar, chalcedony, ferrous dolomite, calcium phosphate, and very thin layers of organic matter.

7. The intimate mutual intergrowth of the organic matter and the feldspathic rock.

8. The gradual transition between the feldspar's microlitic aggregates, which are almost without effect on polarized light, and its clearly crystallized varieties.

9. The participation of feldspar in the construction of spherulites, which obviously are diagenetic formations.

Taking into account that albite predominates quantitatively in spite of a significant admixture of other minerals, it seems appropriate to call them "albitolites," in order to differentiate them from the "albitites," which are of a magmatic origin.

Let us bring forth certain considerations concerning the formation of these peculiar rocks.

Table 5

Results of the spectrographic analysis of feldspathic rocks investigated

Analyses Table 2	Very many	1% many	0.1% present	0.01% few	traces
II	Si, Al, Mg, Ca, Fe, Na	Mn, Ti	V, Cr, Cu, As, P, Sb, Ba	Ni, Co, Zr, Pb, Y, Yb	Mo, Ag, Sn, Ga
III	Si, Al, Mg, Ca, Fe, Na	—	Mn, Cu, As, K, Sr, Ba	Ni, Co, Ti, Zr, Pb	Ag, Ga

Relying on Eytel's data about the exothermic character of the reactions of feldspar formation, and taking into account the characteristics of the new mode of feldspar formation in sedimentary rocks, I.A. Preobrazhenskiy considers them, just as Kayye does, as normal sedimentary minerals [6].

Other investigators (except V.P. Baturin), having studied the feldspars of sedimentary rocks formed by a new mode, assume that the deposition of these minerals in the sedimentary strata took place under physical-chemical conditions entailing the formation and the subsequent transformation (diagenesis, epigenesis), of the very same strata [3, 13, 14]. This is shown in the recently completed review by L.V. Pustovalov [7] of the principal literature on feldspars in sedimentary rocks.

At the same time, it is obvious, that conditions favoring feldspar formation on such a large scale as has been described above, occur comparatively rarely during sedimentation. The presence in the basin's waters where the sedimentation takes place of sufficient concentrations of such constituents as sodium, aluminum, and silica, constitutes one of the requirements of such a process. Their concentration, the conditions of their precipitation, and their mineral form depend upon a series of factors, including the petrographic composition of the drift area, the character of the relief, the climatic conditions, the vegetation, the size and the orientation of the reservoir, and so on, all of which determine the hydrochemical nature of the basin.

In the monograph on sedimentation in contemporary water basins, N.M. Strakhov [10] provides a classification of hydrochemical basins, recognizing essentially different types of hydrochemistry for arid and humid climate basins. Characterizing semiarid zones water basins, he relates to its specific characteristics "the extreme variety of hydrochemical types of water, the progressive salinification of the basins, the increase in their alkilinity, and the appearance of their highly alkaline facies with stable and highly oxidizing conditions of water in the great majority of reservoirs, the relative scarcity of organic matter in these basins, and its decreasing importance in the lakes' geochemistry [10, p. 477]. In such lakes, sodium and magnesium carbonate concentrations appear as the last members of the chemically formed sediment accumulation. N.M. Strakhov noted that the sodium type basins are distributed around mountainous regions or are present at their periphery and occur either in areas of massive crystalline rocks (Sevan, Tibet, North America and Trans-Baykal), or in sectors of arkosic sandstone [9].

Such a position is comparable with that of the described stratum basin of sedimentation. The paragenesis of Lower Permian redbed minerals in the North Caucasus, the composition, the texture, and the color of the rocks attest that the accumulation of the sediments took place in basins with the characteristic hydrochemical peculiarities of semiarid zone lakes. It must be noted, that the hydrochemical regime corresponding to the arid climate was not recognized at once. It seems, that the climatic conditions and the hydrochemical regime of the basins were not stabilized in the course of the prolonged period of formation of the lower redbeds, and of the middle variegated suites of the lower redbeds (P_1^a and P_1^1). The development within the redbeds of gray and greenish bands, enriched by finely dispersed organic matter, and in places containing interstratifications of coal-like argillites, attests to that.

The combination of the criteria points nonetheless to the deposition of Lower Permian redbeds in reservoirs of a hydrochemical type similar to the arid climate basins.

As to the siliceous rocks, their appearance seems to be unquestionably linked with the action of two factors: the orogenic and volcanic [10, 11, 12]. Inasmuch as in the Lower Permian redbeds the silica-forming organisms are not only absent, but, in fact, no trace of organic life has ever been recognized, the high amount of SiO_2 in the basin's waters is apparently connected with the influence of volcanic processes. It may be assumed that the pneumato-hydrothermal activity linked with the flow of extrusive rocks, resulted in the enrichment of the basin's waters with silicic acid. This phenomenon is considered by N.M. Strakhov [10, 11] as one of the typical traits of the chemistry of the extrusive sedimentary type of sediment accumulation.

The fixation of silicic acid in the precipitation with an excess of Na ion in the solution is possible in the form of "liquid glass" as, likely, in the form of a complex aluminum silicic coagulum bearing Na as an absorbed base. It is interesting to note in this connection, the Yu.V. Kazitsin's communication [4] concerning the discovery of a sodium-aluminum-bearing opal, which he called "bobkovite."

The decrystallization of the complex silica and aluminum coagula with the absorbed Na during the rock's lithification and the diagenetic processes, probably is the result of the formation of microlitic albite aggregates, and the "ejection" of the excess of SiO_2 in the form of rounded opal and chalcedony as may be observed during a microscopic study of certain varieties of dolomitic-feldspathic rocks described by us above.

The relationship of these formations to the

Table 6

Table of age-relations of various morphologic types of albite in the feldspathic rocks investigated

Morphologic types of albite	Stages of sediment accumulation		Metamorphism
	Sedimentation	diagenesis	
"Isotropic" (primary coagulum)	———		
Microlitic		———	
Spherulitic		———	
From veinlets			———

diagenetic ones is determined: 1) by the adaptability of the lenses with spherulitic texture to determined spots in the layer's section, and the presence within them of interbeddings with a thin bedding, which speaks in favor of an in situ recrystallization of the rock without substantial displacement of constituents; 2) by their intersection with albitic and anthraxylon veinlets, already obviously linked with the metamorphic stage of the rock.

Judging by the morphology of the albitic veinlets and the control of their spreading by the boundaries of the dolomitic-feldspathic layer, there is no basis for doubting the formation of these veinlets at the expense of albite redeposition in the course of the regional metamorphism process.

The frequent paragenesis of the redeposited albite with a coal-like organic substance is apparently explained by the fact, that the alkaline solutions contributing the silicic acid, act aggressively upon the humic substance of the deposited organic silt, thus dissolving it. The dissolution of the organic matter is accompanied by its oxidation, by the formation of CO_2, at whose expense its content in silt decreases, probably nearing the optimum required for the formation of the albitic molecule.

These conditions contribute to the appearance of close mutual intergrowths of diagenetic albite and organic matter.

The growing relationships of the various morphologic types of albites are in accord with the outline given in Table 6.

It seems to us that the verification of the rock-forming significance of the newly formed feldspar in sedimentary rocks, points to the possibility of the existence of a particular type of hydrochemical reservoir in semiarid zones, where mineral formation is determined by the influence of high alkaline concentrations on one hand, particularly Na, brought by vadose waters from the drift zone, and by the hydrothermal solutions linked with silica-contributing volcanic processes, and possibly some other constituents, on the other.

Thus in our opinion, albitolites may be looked upon as being characteristic rocks of extrusive sedimentary origin, associated with ferrous dolomite and low-grade phosphoritic ores.

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THE PETROGENETIC AND CHEMICAL CHARACTERISTICS OF CERTAIN TYPES OF BROWN COAL SUBSTANCE[1]

by

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Questions of coal terminology and classification are at present under much discussion in the world literature.

The existing classification, based upon the macerals in the coal, at one time of much significance in the development of coal petrography and chemistry, now no longer completely corresponds to new data on the composition, the genesis, and the qualities of coal.

The substance of coal, of course, is heterogeneous: it is composed of microconstituents whose combination determines the genetic characteristics of the coal as well as the physical characteristics. However, the properties of the microcomponents themselves still are insufficiently known. This explains the present lack of uniform opinion among coal petrographers on the quantity of microconstituents which are indispensable for the typification of coals, or for the determination of their quality by petrographic criteria.

For this purpose, it is necessary that a complex study be made of the content of the microconstituents forming the coal, by using in combination petrographic, chemical, and physical methods of investigation, and that the study of the structure of the coal seam, and that of the coal-bearing stratum be made as a whole. The knowledge of the properties of the coal microcomponent is particularly important for the solution of problems of rational utilization of coals in the chemical industry, to the recovery of rare elements, and the obtaining of metallurgical coke from coals utilized as power fuel.

The present paper gives an account of some results of petrographic and chemical investigations of the coal microcomponent substance belonging to vitrain and fusain (vitrinite and fusinite) groups. The work was performed under the direction of V.S. Yablokov.

All red and reddish-brown microconstituents observed under the microscope through transmitted light, as we know, belong to the vitrinite group. They were generated as a result of plant-matter maceration, and they are normal elements represented by telinite[2] (vitrain, xylovitrain, xylene), and various forms of a transparent mass corresponding to collinite.

Similarly, the fusinite group incorporates all black and black-brownish microconstituents, which appear to be the end-product of the fusinization process. To the fusinite group are related: fusinite (typical fusain, xylenofusain, xylovitrain-fusain and vitrain-fusain), sclerotinite, micrinite (the opaque and semitransparent matrix), and semifusinite.

Jurassic hard brown coals of the thick Bogoslov deposit seam (eastern slope of Northern Ural), and Tertiary earthy brown coals of the thick seam in the Yermolayev deposit of the Bashkir A.S.S.R. were used as material for these investigations.

To determine the properties of the separate constituents of the vitrinite and fusinite groups, coals were used, in which one or the other constituents was predominant.

Among the coals of the Bogoslov deposit, four types were investigated: the telinite, collinite, fusinite, and micrinite. The designation of the types were made according to the predominant constituent in the given coal. These coals, except the micrinite, were also investigated in the Yermolayev deposit. Let us note, that the telinite and collinite types of coals generally correspond in their composition to the clarain with a xylovitrain-vitrainic jellified substance, and to clarain with an homogenous maceral ascertained by us and K.I. Inosova (Artemuglegeologiya

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[1] O petrogeneticheskikh i khimicheskikh osobennostyakh nekotorykh tipov veshchestva burykh ugley.

[2] The classification of the microconstituents is given after the nomenclature adopted during the All-Union Conference of Coal Petrographers. (The old terminology denominations are given in brackets).

Table 1

Petrogenetic and physical chemical characteristics of certain types of brown-coal substance

Peat Accumulation facies	Medium	Processes		Substantial composition in %: collinite	telenite	fusinite	micrinite	cutinite	Type of coal	Bogoslov Deposit: Output of humic acids in %	Bogoslov Deposit: Proprieties of 0.02% of: Thrshld. coag. (meq/l sol'n)	Bogoslov Deposit: Proprieties of 0.02% of: Optic density in violet part of spectrum	Yermolayev Deposit: Output of humic acids in %	Yermolayev Deposit: Proprieties of 0.02% of: Thrshld. coag. (meq/l sol'n)	Yermolayev Deposit: Proprieties of 0.02% of: Optic density in violet part of spectrum	The residual products after the drained separation of humic acids
Heavily irrigated stagnant swamp	Anaerobic	Maceration	brief	—	over 95	—	—	—	Telinite	9-11	19-22	1.14	24-26	22-26	0.53-0.71	Water-conducting vessels
			long	85	5	3	2	5	Collinite	17-19	18-17	1.5	44-50	22-18	0.83-1.20	Cutinized elements, unifusinitized tissue, mineral admixture
Relatively dry stagnant swamp	Aerobic	Fusinitization		—	—	over 95	—	—	Fusinite	2-3	9	2.2	4.5	7	1.85	Fusinitized tissue
Heavily irrigated flowing swamp	Anaerobic-Aerobic	Maceration with the ensuing fusinitization		2	3	5	80	10	Micrinite	63-70	9-7	2.6-3	—	—	—	Cutinized elements, fusinitized tissue, and mineral admixture.

Trust) in the Donets Basin coals (L.I. Bogolyubova and V.S. Yablokov, L.I. Bogolyubova, Yu.A. Zhemchuzhnikov — [1, 2, 4]). The results of the investigation are compiled on Table 1.

Let us consider the petrographic characteristics and the genetic particularities of the coals listed here.

The telinite (Fig. 1, Table 1) is made up of more or less coarse fragments of trunks and stems of telinite plants which appear under the microscope to possess a red-orange color, and disclose a varied preservation of cellular structure of the vegetable tissue, which may be clearly expressed to totally absent. Telinite constitutes more than 95% of the coal.

Between the fragments of trunks and stems, a small quantity of transparent material is present (as much as 5%), which is collinite with included single microspores and micrinite particles. The telinite coals make up only a small part of the composition of the seams of the Bogoslovsk as well as of the Yermolayev deposit. However, in one series they form exposed layers which may be used as markers in establishing cross sections on the surface. In addition, the telinite coal represented in the form of separate, coarse or minute fragments, takes part in the composition of other types of coals, modifying their banded or striated structure.

The collinite (Fig. 2, Table 1) is made up a mass (matrix) — collinite, which is structureless or discloses a flocculent structure. With the collinite content, about 85%, other elements are present in small quantitites; among which are cutinized element, 5%; black micrinite particles, single resinous corpuscules, scarce telinite fragments, 5%; and fusinite, 3%. The collinitic coals predominate in the Bogoslov and Yermolayev deposits.

FIGURE 1. Telinite.
Bogoslov Deposit: transmitted light, magnification 44X with parallel nicols.

Table 1 shows that the telinitic and collinitic coals are related to a facies marked by a strongly irrigated stagnant swamp, characterized by a reduction medium, and by anaerobic bacterial activity. These conditions contributed to the maceration of the vegetable material, whose initial stage was characterized [Yu.A. Zhemchuzhnikov and A.I. Ginzburg, 5] by the swelling of the cellular walls, and by the disintegration of the tissues, and in the final stage by the liquefaction and coagulation of products of the first stage.

The basic distinction in the formation of telinite and collinite consists in the fact, that the former is the result of an incomplete decomposition of the plant material (nearly

100% of the telinitic substance). This decomposition ceased at the beginning of the maceration process, as a result of which separate fragments of coal are sharply separated from one another, and have preserved their form and, commonly, a more or less apparent cellular structure of the plant tissue. The collinite appears to be the result of the total decomposition of the plant material (85% of collinitic substance), with the ensuing formation of a liquid, flowing substance, capable of fulfilling the role of the cement in the coal.

P.P. Timofeyev [12] established that coal seams composed of telinite can be attributed to alluvial, coastal, and specifically maritime media, in which a sharp variation of conditions is noted before and after the peat accumulation. The seams, composed of collinite, are linked with coastal maritime conditions, characterized by analogous conditions before and after the accumulation of peat.

Therefore, the differences between the telinite and collinite find corroboration in the general conditions of sedimentation.

The fusinite (Fig. 3, Table 1) represents an accumulation of fusinized fragments of stems and trunks with a characteristic silky luster, composing more than 95% of the coal substance. Under the microscope, separate fragments of trunks and stems disclose a well-expressed cellular structure of the plant tissue with finely marked black walls of cells, and with more or less large cavities. The yearly rings are commonly clearly visible within the structure of the tissue.

The fusinitic coals are related to relatively dry, swamp facies characterized by an oxidizing medium contributing to the development of anaerobic bacterial activity and to intensive oxidation and dehydration of the plant material accumulating in the swamp. The fusinitic coals of the Bogoslov and Yermolayev deposits are seldom encountered in the form of small (thin) layers. In the other deposits, for example in the Angrenov (Central Asia), they constitute entire coal seams.

FIGURE 2. Collinite.
Bogoslov Deposit: transmitted light, magnification 44X with parallel nicols.

The micrinite (Fig. 4, Table 1) is characterized by a petrographic composition showing a sharp predominance of micrinite with an admixture of semifusinitic attritus, constituting 80% of the coal mass. A small quantity (10%) of cutinized elements, resinous corpuscules, and, more or less, coarse grains of terrigenous rocks (quartz and clayey minerals) are observed within the micrinite. Such coals form continuous layers within the seam, commonly passing in plane or in section into coal-like argillites.

The position of the micrinite within the section of the coal seam and the significant

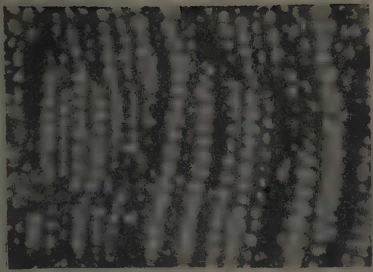

FIGURE 3. Fusinite.
Bogoslov Deposit: transmitted light, magnification 44X with parallel nicols.

mineral admixture allow its attribution to a flowing swamp facies, where the reducing medium — as a result of the heavy irrigation — might change to a more or less oxidizing one, depending upon the measure of water saturation by air oxygen as a consequence of its motion.

Under these conditions the plant matter underwent changes as a result of two processes overlapping one another: maceration and then fusinization (oxidizing). A.B. Travin has quite legitimately attributed micrinitic coals to the primarily oxidized ones.

To demonstrate the chemical characteristics of these coal types, we used methods which amount to the determination of the output of humic acids, their threshold of coagulation,[3] and their optic density.[4]

The extraction of the humic acid was carried out by a generally accepted method. The threshold of coagulation and the optic density of humic acids were determined by the T.A. Kukharenko method [10] worked out in the Institute of Mineral Fuels of the U.S.S.R., Academy of Sciences applicable to brown and oxidized coals on the basis of methods known in soil science. In the course of these operations, we took advantage of T.A. Kukharenko's counsel on investigation problems as well as those on the substantiation of the obtained data. The chemical analyses were made by the laboratory worker, L.N. Simonov.

As a result of the application of the described methods for studying coals, T.A. Kukharenko clarified the differences in the brown-coal properties at various stages of coal formation, and indicated the differences between the brown coals, and the weathered regular (bituminous) coals [6, 7, 8, 10]. This

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[3] The "threshold of coagulation" is the smallest quantity of an electrolyte required for the coagulation of a given quantity of humic acids during one hour. The magnitude of the threshold of coagulation characterizes the degree of dispersion of the humus substance particles [9 and 10].

[4] The substance's optic density is the relation of the force of the light entering that substance to the force of the light having passed through it. The optic density's magnitude expresses the degree of the nucleus condensability in the macromolecule of the substance of the humus [8 and 9].

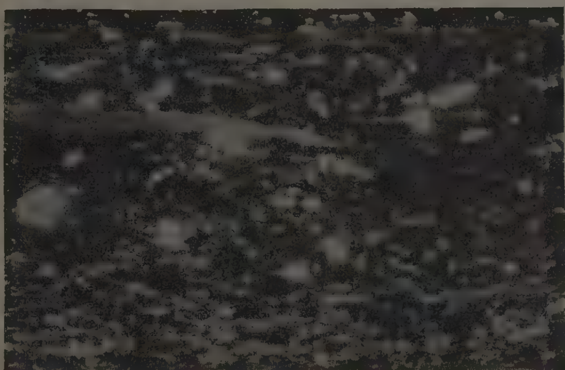

FIGURE 4. Micrinite.
Bogoslov Deposit: transmitted light, magnification 44X with parallel nicols.

work was performed on average samples of coal seams, whereas our attention was concentrated on studies of separate types of coal matter, using types of coal with either microconstituent.

It is seen from Table 1 that all these coals differ among themselves in the output of humic acid, the threshold of their coagulation, and their optic density.

Let us compare the chemical properties of telinite and collinite coals, and also of fusinite and micrinite. The telinite of the Bogoslov deposit is characterized, in contrast to the collinite, by a lesser output of humic acid (9-11 and 17-19), by a larger threshold of coagulation (19-22 and 18-17), and by a lower optic density (1.14 and 1.5). The same relationship in humic acid output and characteristics is observed in the telinite and collinite of the Yermolayev deposit, which are in a lower stage of coal formation in comparison with those of the Bogoslov deposits, namely: by comparison with the collinite, the telinite of the Yermolayev deposit have a nearly double humic acid output (24-26 and 44-50), a higher threshold of coagulation (22-26 and 22-18), and a lower optic density (0.53-0.71 and 0.83-1.20). According to concepts of coal chemists the data, with respect to the chemical investigations of both types of coals, contribute evidence to the difference in the molecular structures of telinite and collinite. The collinite's macromolecule has a more condensed aromatic ring and shorter side chains than that of the telinite. The infrared spectra, studied by O.I. Zil'berbrant (Institute of Mineral Fuels of the U.S.S.R. Academy of Sciences, V.I. Kasatochkin's laboratory) (Fig. 5) point to the different composition of the macromolecules of the telinite and collinite, at lower stages of earthy brown formations. We see on the spectra that a peak is indicated for the telinite, which according to O.I. Zil'berbrant's explanation, corresponds to the oxygen-containing grouping of the ordinary type of ether. This peak is absent in the collinite spectrum.

The study of acid products of the thermohydrolytic coal splitting carried out by V.G. Nemtsova (U.S.S.R. Academy of Science, Institute of Geological Sciences, Laboratory of V.I. Zabavina) has shown that the Bogoslov telinite and collinite coals differ by their functional group content (OH and COOH) in the acid products of the residual coal after the last splitting.

The microscopic study of the residual products, after draining of humic acids, has shown sharp differences between the telinite and collinite (Table 1). The residual products of the telinite constitute water-conducting vessels — tracheids. Their substance,

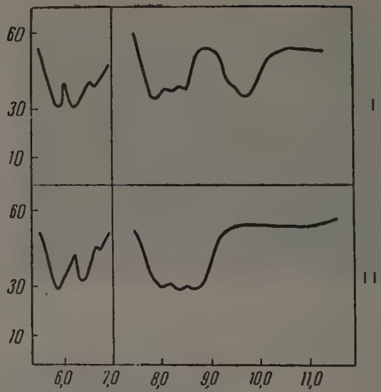

FIGURE 5. Infrared spectra of ash-free earthy brown coals of the Yermolayev Deposit.

I -- Telinite; II -- Collinite.

contrary to the substance of parent lignites, has yellow coloring under crossed nicols. It is anisotropic and it discloses a high birefringence.

The residual products of collinite coals almost, in no case, contain highly birefringent elements. They are represented by spore sheaths, by cuticula fragments, and by some other stable elements.

Thus, telinitic and collinitic substances of brown coals vary according to a series of above indicated properties.

The disclosed differences in the properties of telinite and collinite in the brown coals corroborate the data obtained during the complex petrographic and chemical investigations of the Donbass coals [1, 3, 4], and show that the telinite matter (xylovitrain-vitrain), differing in that of the collinitic one, has a greater degree of loss of volatile matter, a greater heating value, a greater clinkering capacity, and contains more hydrogen and less oxygen.

The above-presented data permit the conclusion of the indispensability of a separate calculation for telinitic and collinitic matter during petrographic studies of coal. This conclusion appears to be accurate for clarain coals with more than 50% of jellified material. For coals of the durain category, which are characterized by a low content of jellified material, the separation of telinite from collinite has no substantial significance.

Table 1 shows that the common characteristic of fusinite and micrinite lies in the similar properties of their humic acids,

expressed in the low threshold of coagulation (9 and 9-7), and a high optic density (2.2 to 2.6-3). However, these similar humic acids are found in sharply different quantities in both types of coals. In the micrinite they form nearly the total mass of the coal — 63% to 70%; in the fusinite their share is only 2% to 3%. This implies that the micrinitic substance is not identical, as far as their properties are concerned, to the fusinitic substance. The study of residual products obtained after the draining of humic acids, also stresses this fact. The residual products of the fusinite represent a typical fusain, whose quantity nearly equals that of the original. In the residual product of the micrinite there is a mineral substance, some cutinized elements, and an insignificant admixture of fusinite.

It is appropriate to note that fusinite coals of the Yermolayev deposit are similar to those of Bogoslov in their chemical properties and their residual products characteristics, and this in spite of the fact that they are representative of a lower stage of coal formation. This indicates that the fusinitic substance changes little in the process of coalification, and that its properties are basically determined during the period of the primary decomposition of the vegetable material.

It is thus impossible to include, in the course of petrographic investigations of brown coals, the fusinitic and micronitic substances into a single fusinite group, because this leads to the obscuring of the various properties of both substances. A separate determination of fusinite and micrinite is indispensable mainly for the durain type of coals with predominant fusinitic microconstituents. For the clarain type of coals, the separation of fusinite and micrinite is not deemed indispensable because of a strong development of macerated material within them, and of only small quantities of fusinitized matter.

The investigations carried out represent a first stage on the road leading to the clarification of the properties of macerated and fusinitized microconstituents. The investigations have shown the nonequivalence of telinite and collinite properties united in the group of vitrainite, and also of fusinite and micrinite entering in the fusinite group. These differences in the properties of microconstituents are linked with the conditions of transformation of vegetable material during the period of peat accumulation.

In future work in this field, it is indispensable that a more precise determination of the properties of coal microconstituents, modified by the character of the original material, be made.

The determination of the properties of microconstituent substances, and of the causes of their differences, will permit a deeper understanding of the nature of coals, and this should in its turn bring nearer a solution of the problem of better coal utilization in the economy.

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THE CARBONIFEROUS SYSTEM AND ITS PRINCIPAL STRATIGRAPHIC SUBDIVISIONS[1,2]

by

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At the Third Congress on Geology and Stratigraphy of the Carboniferous at Geyerlen and at the Nineteenth Session of the International Geological Congress the question of subdivision of the Carboniferous and even of abolishing the term as the name of a single geologic period was raised. It will be of utmost importance to the Twenty First Session of the International Geological Congress to settle such problems as unity, scope and boundaries of the Carboniferous and its principal subdivisions.

The purpose of the present report, which expresses the point of view held by a majority of Soviet geologists, is to make a concrete proposal of some generalized classification of the Carboniferous subdivisions for discussion and acceptance.

GENERAL STATEMENTS

In dealing with the scope and subdivision of the Carboniferous it is only natural to start by defining the principles of separation and subdivision of geologic systems. A system consists of strata which form a part of a sequence deposited during the corresponding period, i.e., it is a rock unit of the second order in the general stratigraphic scheme. Systems in turn consist of sediments belonging to three or sometimes two divisions. These correspond more or less to major stages in evolution of the earth, stages which have usually been marked by major oscillatory movements of the crust. There are evidences of diastrophism and intense magmatic activity at or near the boundaries of adjacent systems, and also sharp changes of facies.

Certain types of sediments are typical of some systems. Lithology is not sufficient for characterization of individual systems and their subdivisions and the deciding role is played by paleontologic evidence.

Paleontologically, systems correspond to large intervals of time during which faunas and floras developed. Systems are defined by families and genera that reached their best representation through the entire system or are even proper only to the system. The same is true of floral genera and species.

Such concepts do not everywhere apply satisfactorily to the Carboniferous within its present framework.

In attempting to deal with such stratigraphic problems as scope and limits of individual geologic systems and their major subdivisions, the main guiding principle is the evolution of the organic world. Different stages of this evolution, fixed by fossils, portray conditions of historical development of the earth. Consequently, the paleontologic criterion of rejuvenation of the organic world is important to the separation of systems and their subdivisions.

The particular significance of this principle is due to its reflecting best, in evolution of the organic world, the law of irreversibility of evolution and non-repetition of consecutive stages of evolution. Lines of demarcation in development of the organic world reflect changes of physical and geographic conditions that had affected very extensive areas. These

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[1] Kamennougol'naya sistema i yeye osnovnyye stratigraficheskiye podrazdeleniya.

[2] Report of the Commission on Stratigraphy of the Carboniferous to the National Committee of Soviet Geologists, delivered at the Fourth Congress on Stratigraphy and Geology of the Carboniferous at Geyerlen. This report has been prepared under auspices of the National Committee of Soviet Geologists.

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lines of demarcation acquire almost worldwide significance.

Marine faunas lend themselves particularly well to solution of general stratigraphic problems. In comparison to land faunas and floras, marine faunas are less affected by fluctuations of local physical and geographic conditions, particularly climatic conditions (because ecologic conditions in seas are more constant and are fairly uniform over larger stretches of the sea than the land). Many representatives of marine faunas spread over large areas almost instantaneously, relative to geologic time.

Also, considerable quantities of marine fossils are well preserved. In comparison with continental sediments, marine strata containing such fossils remain fairly homogeneous and persistent over large areas.

These are the initial principles used by authors of this report as a basis for their proposals on the scope and main stratigraphic subdivision of the Carboniferous System.

THE ENTITY OF CARBONIFEROUS SYSTEM

The Carboniferous system, recognized in 1822, represents a single stage in geologic history and in development of the organic world. It was not through an oversight that European geologists, establishing this system more than 130 years ago, did not think of subdividing it. Quite to the contrary, there were attempts to enlarge this system by incorporating the Permian and naming the whole the Anthracolite or Permo-Carboniferous.

The unity of the Carboniferous system follows first of all from the fact that there were no substantially significant evolutionary changes during the entire Carboniferous and most of the Permian which would indicate a radical transformation in the organic world. Therefore, an attempt to divide the Carboniferous into two separate systems is a purely arbitrary attempt to break up a single stage of evolution in the organic world, no matter on what level the subdivision is to be made. This view is confirmed by analysis of the stratigraphically most important groups of marine fauna.

Thus, the Carboniferous stage in development of foraminifera possesses the following features: 1) the order of Endothyrida with its many-chambered spiral forms reached its best development in it and two of its super families, Endothyridea and Fusulinidea, were developed entirely during the Carboniferous; 2) the order of Ataxophramiida appeared for the first time and two of its genera, Tetraxis and Globivalvulina, had their best development, while some genera, like Cribrostomum and Deckerellina, of the new order Textulariida, were restricted to the Carboniferous; 3) the decadence of primitive, single-chambered forms is characteristic of the lower Paleozoic; 4) the Carboniferous was the only time of existence of archaeodiscides with their keriothecal vitreous walls and the time when the first lasiodiscides appeared (Howchinia and Monotaxinoides); the Carboniferous was characterized by an almost total absence of lagenides.[3] These peculiarities of Carboniferous foraminifera may be noted in practically all the countries of the world and distinguish the Carboniferous from both the Devonian and Permian.

The Carboniferous is characterized by a peculiar complex of rugose corals which are very distinct from a similar Devonian complex and somewhat different from the Permian complex. Practically all the families of the order of Cystiphillida had died out in the Devonian, only the Caninidae family having survived and fluorished. Toward the beginning of the Carboniferous the families Streptelasmidae, Syringoxonidae, Disphyllidae, Spongophyllidae and others which were so typical of the earlier Paleozoic died out. The families Lithostrotionidae, Clysiophyllidae, Caninidae, Lophophyllidae, Bothrophyllidae, Petalaxidae appeared or flourished during the Carboniferous. Despite peculiarities of each such complex, corals were developing continually during the Carboniferous and the coralline fauna of the Carboniferous is definitely a single stage in the evolution of that group.

The unity of the Carboniferous is no less sharply shown by the development of brachiopods. Suffice it to say that the entire Carboniferous is distinguished by the maximum flourishing of such large and characteristic groups as the spirifers and productides.

The history of development of ammonoids is that of peaks alternating with troughs during the entire Paleozoic. Such crises in evolution of ammonoids, which brought about almost a total extinction of some phylogenetic branches, mark transitions from Devonian to Carboniferous and from Permian to Triassic. The Carboniferous and Permian periods constitute one single stage in development of ammonoids during which they invariably and consistently improved their organization.

In particular, the sub-order of Goniatitina, so large and so varied, became differentiated at the boundary between the Devonian and

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[3] Lagenidea, known since the Devonian, reached their peak of development during the Permian.

Carboniferous. Development of this sub-order continued during the entire Carboniferous and Permian Periods. Differentiated into numerous families during Carboniferous and Permian time, this sub-order became the principal group of cephalopods and, therefore, the boundary between the Carboniferous and Permian is less sharply defined on the basis of cephalopods than boundaries between some other systems. However, development of ammonoids gives no basis whatsoever for division of the Carboniferous into two separate systems.

An analysis of the stratigraphic distribution of Carboniferous pelecypods indicates that representatives of many families and genera are scattered through the entire Carboniferous and are indexes exclusively or at least predominantly to this particular system. Among these are the following genera: Anthraconeilo, Polidevcia, Edmondia, Conocardium, Sanguinolites, Ianesia, Soenomorpha, Aviculopecten, Streblochondria, Pernopecten, Anthraconauta, etc.

Land vegetation during the Carboniferous was characterized by the development of a peculiar flora with dominant lepidophites, calamites, ferns and pteridosperms. The most significant change in floral composition, at least in Europe, occurred during the Visean age. During that age, elements of the Devonian archaeopteric flora, which still persisted during Turnei and Early Visean time, became extinct.

The latest data on Carboniferous floras of European U.S.S.R. testify to the homogeneity and unity of composition of the flora of the entire Namurian stage. These data contradict views of V. Gotan on heterogeneity of the Namurian in the paleobotanic sense, i.e., absence of a transitional flora and existence of a "floral gap" between the Early (A) and Late (B) Namurian.

The unity of the Carboniferous in development of the land flora is also confirmed by studies of spore and pollen complexes. The generic and species composition of Carboniferous spores and pollen is varied and is represented mainly by spores of bryophytes pteridosperms and pteridophytes as well as by pollen of cordaites and the oldest conifers. Many species of spores are characteristic only of the Carboniferous System. Among typical Carboniferous spores there are groups which, having appeared near the beginning of the Carboniferous, became extinct near its end or at best only partly survived into the early Permian. The chief of these groups is quantitatively abundant, and, therefore, may be used as indexes of composition of spore complexes in Europe and in America.

All this confirms our view on the unity of the Carboniferous as a single stage in evolution of the organic world. During the Carboniferous Period there were no observable large, transitory moments, contemporaneous to different groups of organisms, which would correspond to the demarcation line between two systems.

DIVISION OF THE CARBONIFEROUS INTO TWO SYSTEMS OR SUB-SYSTEMS

It is advisable to consider this question because of the proposal of division of the Carboniferous into two systems or into two sub-systems by the American Commission on Stratigraphic Nomenclature. Different arguments have been advanced in support of such proposals. There is hardly any need to consider as a valid argument remarks that in North America there has been accepted the division of the Carboniferous into the Mississippian and Pennsylvanian subdivisions which American geologists call systems. The reason for such a differentiation was partly based on local geologic development, but stems largely from traditional usage of prospectors in that country. Similarly, the argument that facies differences in the Dinantian of Western Europe suggests two different systems or sub-systems cannot be taken seriously. These facies are, on one hand, marine sediments and, on the other, coal measures of the Namurian, Westphalian and Stephanian. That is a local feature characteristic of a certain region and not observable in many others.

Therefore, it will be necessary to consider only biostratigraphic arguments used in favor of dividing the Carboniferous into two independent systems. Substantial changes in faunal and floral composition are generally cited as an argument for differentiation between the lower and middle subdivisions. This will be treated in another part of this report. However, the following conclusions, to summarize characteristics of development of the organic world, may be given here:

1. The breaking points in development of all principal marine faunal groups between the lower and middle carboniferous were not synchronous nor sharp enough to warrant differentiation of independent systems.

2. The most significant breaking point in development of the flora was not between the Visean and Namurian of Europe (equivalent to Mississippian and Pennsylvanian of North America) but within the lower Carboniferous, in the middle Visean according to plant fossils, and between Thurnean and Visean according to spore evidence. Obviously, major floral

changes do not correspond to the boundary between the Mississippian and Pennsylvanian which has been proposed and used in lieu of a unified Carboniferous System. At that particular boundary, floral changes are less sharp than at the boundaries between some other geologic systems, yet there is no reason for remodeling these systems also.

For example, the Lower and Middle Devonian psyliphytic flora was succeeded by the Upper Devonian archaeopteric flora, and the Upper Cretaceous by the dominance of angiosperms. Notwithstanding such changes no question has ever been raised on subdivision of the Devonian or Cretaceous Periods.

Thus, there are no serious biostratigraphic reasons for substitution of two systems for the Carboniferous. Nor do any other data suggest such a substitution.

Consequently, the proposal of subdivision of the Carboniferous into two independent systems, Mississippian and Pennsylvanian, should not be accepted. It would only lead to an arbitrary break-up of what is a single stage in evolution of the organic world. It is also incompatible with the principle of historical priority.

Neither is the subdivision of Carboniferous into two subsystems warranted. First of all, the general rule is to subdivide systems into three divisions. The "subsystem" is lacking among divisions of the general stratigraphic scale approved by the International Geological Congress. The subsystems that were separated out in the past, for instance, within the Tertiary System, were provisional. It was intended to convert such subsystems into systems as has been done in fact with the Paleogene and Neogene.

Inasmuch as the necessity for preservation of the Carboniferous as a single geologic system is well founded, the proposal for its subdivision into subsystems should be rejected in order to eliminate any future attempts at revision.

BOUNDARIES OF THE CARBONIFEROUS SYSTEM

The question of the lower boundary of the Carboniferous System has already been debated at the first two Congresses on Stratigraphy of the Carboniferous at Geyerlen. At the First Congress in 1927 it was decided to draw it at the base of the Pericyclus zone. At the Second Congress in 1935 this limit was lowered and fixed between zones of Wocklumeria and Gattendorfia in the cephalopod facies and also between Etrain zones K and Z in the coral and brachiopod facies. The principal criterion for such a demarcation was the disappearance of Clymeniae at the end of the Devonian and a somewhat later appearance of some genera and species of goniatites. However, the presently available data indicate that Clymeniae continued to exist up to the very end of Wocklumeria time and that the first Carboniferous goniatites appeared prior to extinction of Clymeniae. The Clymenia complex of the Wocklumeria zone is not purely Devonian in character but is distinguished by the appearance, together with goniatite shells, of peculiar families — Woclumeriidae, Glatziellidae and Parawocklumeriidae — as well as some new typical representatives of other families. The Wocklumeria zone is also characterized by the appearance of new species of goniatites characteristic of the Carboniferous, Imitoceras (I. subbilobatus Mstr., etc.) and the entirely Carboniferous genus Gattendorfia (subgenus Bolvia). It is significant that cephalopods typical of the Wocklumeria zone are not infrequently present in strata of the Etrain zone and its equivalents, all of which are of the same age and all of which represent coral-brachiopod facies.

The Etrain zone at its type locality in northern France is characterized by a mixed Devonian-Carboniferous faunal complex. There appear for the first time Carboniferous corals, such as Caninia dorlodoti Salée, and brachiopods (Plicatifera niger Goss, Spirifer tornacensis Kon and their replacement species, Tylothyis laminosus McCoy, etc. Equivalents of this zone, widespread in some countries, are universally characterized by the appearance of new Carboniferous elements alongside older Devonian forms. The introduction of new forms in the marine fauna occurred at given stratigraphic levels.

Foraminifera in the Etrain equivalents in some regions of the U.S.S.R. (the entire Khovanskiy and Malevskiy units of the Russian platform) are characterized by appearance of the first representatives of the genus Quasiendothyra (group of Q. kobeitusana Raus), frequent Endothyra communis Raus, and rare representatives of the genera Tournevella, Spiroplectammina, Klubovella, Cribroendothyra.

The Etrain horizons of Novaya Zemlya are of a considerable interest in connection with coelenterata since these beds contain characteristic Carboniferous tabulate and rugose corals: Syringopora ramulosa Goldf., S. conferta Keys, Michelinia tenuisepta Phill., Caninia sp. and Lophophyllum, Javorskia, Uralina, etc. on a par with Devonian forms (Stromatoporoidea, Endophyllum). At the base of the Thurnean unit (i.e., Etrain zone and its equivalents) there appear several genera of productid brachiopods (Limnoproductus, Avonia, Buxtonia, Postula, Dictyoclostus) and

and other groups (Rugosochonetes, Punctospirifer, Eomartiniopsis, Imbrexia) which are unknown in Devonian strata. Particularly characteristic is the appearance at the base of the Thurnean of the Carboniferous genus Spirifer s str. That this stage of brachiopod development belongs to the Carboniferous is shown by the fact that all the genera that appeared at that level, continued to exist and rapidly flourished in the late Carboniferous.

At a stratigraphic level approximately corresponding to the lower limit of the Wocklumeria zone, the appearance of these species was accompanied by extinction of numerous Devonian genera (Productella, Agramatia, Chonopectus, Lamellispirifer, Cyrtospirifer, Atrypa). This again confirms the fact that this particular level represents an important threshold in development of brachiopods heralding the beginning of a new stage in their evolution.

Bryozoa, although Carboniferous forms have been insufficiently studied, show a similar sharp change in some regions. Less perceptible is the resurgence of a trilobite complex within that interval. Trilobites continued to exist in the Wocklumeria zone evolving in Late Famen time, but no definite information is to be had at the present time on the appearance of typical Carboniferous forms.

The change in composition of the fish fauna at the upper limit of the Devonian System and within the possible equivalent of the Etrain zone is quite sharp in some countries, e.g., U.S.S.R., England, and Australia. At this stratigraphic level or near it a Devonian complex of placoderms, acanthodes, Crossopterygii and dipnoids were displaced by the Carboniferous fish fauna with its Paleoniscides, sharks, and so forth.

Land flora provides less definite indication as to the likely boundary between the Devonian and Carboniferous. The succession of Upper Devonian archaeopteric flora by the early Carboniferous lepidophyte flora can rarely be ascertained in any single geologic section. Nevertheless, it seems to be clear that the oldest Carboniferous flora, the Thurnean, differed but slightly from familiar Early Visean floras despite the presence of Upper Devonian elements of an archaeopteric flora.

Within distribution limits of Angaran floras, the Bystryana suite of the Minusinsk basin, characterized by a mixed Devonian-Carboniferous complex of floras, might correspond to the Etrain zone.

The data so far considered lead to the conclusion that the lower boundary of the Carboniferous system should be drawn at the base of the Etrain zone in the coral-brachiopod facies, at the base of the Wocklumeria zone in the cephalopod facies and at the bases of their equivalents in all other facies developed in various regions and countries. These stratigraphic levels show the most significant innovations in the principal marine groups. At the same time, this limit should be considered the lower limit of the Thurnean of the lower Carboniferous.

The indicated boundary coincides with manifestations of Early Variscian diastrophism at this level in various countries. It also corresponds to the Martian Phase of Germany and to local unconformities at the bases of Etrain equivalents in many European regions. In North America, the counterpart of these movements is the first phase of Early Variscian diastrophism that developed before deposition of the Kinderhook Series. Suggestions of tectonic movements manifested at that level have also been found in different regions of the U.S.S.R. On the other hand, there are no data indicating extensive diastrophism preceding the beginning of deposition of Gattendorfia sediments.

While the lower boundary of the Carboniferous System can be fixed quite clearly and uniformly on the basis of different groups of marine fauna, its upper boundary is less definite.

It has been mentioned previously that development of the organic world progressed uniformly during the Carboniferous and Permian and without any sharp thresholds or critical moments. This explains the sharpness of the debate on the boundaries between the Carboniferous and Permian. The Soviet Commission on Stratigraphy of the Carboniferous has accepted the base of the Schwagerina zone and its equivalents as the upper limit of the Carboniferous System on the basis of the following biostratigraphic data:

The sharpest boundary between the Carboniferous and Permian is displayed at this level by the evolution of ammonoids. The entire Carboniferous complex of ammonoids differs from that of the Permian by being more primitive and by the predominance of groups with eight septae. During the Permian, the families with more complex sutures became dominant. However, this increase in complexity of organization was not instantaneous; individual families, characteristic of the Permian Period, appeared at different stages in the Carboniferous, beginning in the Namurian. At the beginning of Schwagerina time there were four new families of which Metalegoceratidae, Paragastrioceratidae and Popanoceratidae are the most typically Permian. At the same time a number of genera

of the families developed earlier began to flourish. Representatives of these families were now more organized than their Carboniferous relatives.

An almost complete change of the ammonoid complex took place at the time of the base of the Schwagerina zone.

Less distinct is the boundary, accepted in this report, between Carboniferous and Permian foraminifera. Three principal genera of late Carboniferous fusulinids, Pseudofusulina, Triticites and Rugosofusulina continued to develop during the early Permian, giving rise to many new species. The Pseudofusulina genus was developing particularly rapidly. Triticides, so characteristic of the late Carboniferous, became rare although some new species did develop during the early Permian. Above this threshold genera of the Schwagerinidae family appeared: Schwagerina, Pseudoschwagerina and Paraschwagerina. These genera are widely distributed only in the Schwagerina zone. Only in some regions did representatives of spherical schwagerinids persist up to the later, Artinsky, age. Appearance of Boultenia and of the group of Climacammina grandis coincides approximately with the base of the Schwagerina zone. The generic composition of small foraminifera had not changed much at this boundary.

A substantial change has been noted in the coralline complex — rugose corals — at the base of the Schwagerina zone. Single corals, which predominated during the late Carboniferous were now succeeded by colonial forms of prismatic corallites of the genera Thysanophyllum, Diphystrotion, Wentzelella as well as the aster-like forms, Cysthopora, etc.

At the level equivalent to the base of the Schwagerina zone there was also an essential renewal of the brachiopod complex. Some typically Carboniferous forms of spirifers (genus Choristites) and productids either became extinct or subordinate. New species and genera appeared in all brachiopod groups, particularly among Rhynchonellacea and Terebratulacea. Some genera, that had appeared at the very end of the Carboniferous, now reached their peaks.

All this indicates that from the biostratigraphic point of view, and especially according to ammonoids, the proposed boundary between the Carboniferous and Permian — the base of the Schwagerina zone — is sharp although not associated with any large and widespread manifestations of diastrophism. In favor of this version of the boundary is its acceptance in many countries including those of North America.

The second version of this boundary corresponds to the top of the Schwagerina zone. In favor of this version, which has many adherents in the U.S.S.R. and was adopted in the Chinese Peoples Republic, are the close relationship between the foraminiferal complex of Schwagerina strata and those of the upper Carboniferous, a number of other biostratigraphic data and, finally, historic priority.

The above data forces us to leave the question of demarcation of a boundary between the Carboniferous and Permian still unsettled.

SUBDIVISION

The Carboniferous system, within the scope as stated above, and defined on the basis of the marine fauna, may be naturally divided into three main subdivisions. The three-part division of the Carboniferous conforms to development of land flora and particularly to data from spore-pollen analysis.

The three-part division of the Carboniferous is more than 100 years old. It was R. Murchison who in 1846 proposed subdivision of the Carboniferous system of European Russia into three series: the Lower Limestone with Productus giganteus, bearing very little coal; the Middle or White Moscow Limestone with Spirifer mosquenensis and considerable coal deposits in the south; and Upper Limestone with Fusulina cylindrica which bears little coal in the south.

Subsequently, division of the Carboniferous into three parts was based on foraminifera in Russia by V.I. Meller and still later, toward the end of the last century, by S.N. Nikitin. In western Europe, the Carboniferous was divided into three parts by A. Lapparan and influenced the classical work on historical geology by E. Ogg.

At the present time, the three-fold division has been adopted by many contemporary authors for geologic sections of marine Carboniferous beds in southern Europe, northern Africa and elsewhere.

The three-fold division, based on studies of marine sediments and reflecting the main stages of development of the marine fauna, might well serve as the basis for general international subdivision of the Carboniferous System.

Accordingly, we propose here the following scheme for stratigraphic subdivision of the Carboniferous into divisions and stages:

Division	Stage
Upper	Orenburgskiy Gzhel'skiy
Middle	Moskovskiy Bashkirskiy
Lower	Namurian, Visean Thurnean

The data on evolution of the stratigraphically most important groups of organisms are given at the continuation because basic stages of such evolution bear on the three-fold division of the Carboniferous. Although the main thresholds in evolution of individual groups do not always correspond to the same stratigraphic level, existence of three stages of evolution, which are approximately parallel in time, has been clearly recognized.

Foraminifera. The early Carboniferous stage in evolution of foraminifera ended during the Namurian. The composition of the foraminiferal complex changed gradually. The foraminiferal complex of the Lower Namurian, equivalent to Namur A of western Europe, generally retained its Visean character. A very distinct change in foraminiferal complexes is noted at the stratigraphic level corresponding to Namurian B of western Europe, when most of the typically Visean genera and groups of species became extinct. Several groups, which appeared earlier, began to flourish, some species acquiring essentially new diagnostic features. Primitive members of the Staffella group, like Pseudostaffella antiqua, appear in the upper part of equivalents of the Namurian B.

Near the bottom of stratigraphic equivalents of Namurian C, which in the U.S.S.R. constitutes the bottom of the Bashkirian stage of the middle Carboniferous, no extinctions of genera or species have been noted. However, we find new elements of the middle Carboniferous at this level. The first primitive representatives of spindle-shaped fusulinids (genus Profusulinella) appeared for the first time and genus Pseudostaffella quickly reached its climax in Namurian C. At the same time representatives of genera Ozawainella, Novella and Schubertella flourished at the time of deposition of upper beds of the middle Carboniferous.[4]

The boundary between the middle and upper Carboniferous is less sharply defined on the basis of small foraminifera because their extinction, evidently conditioned by a rapid development of fusulinids, continued through the entire middle Carboniferous. Not all the archaeodiscids and species of Cribrostomum, Deckerellina, Turrispira, Monotaxinoides and Eolasidiscus continued into upper Carboniferous. Fusulinids generally mark the boundary between middle and upper Carboniferous very sharply.

A majority of such genera of the Fusulinidae family as Millerella, Novella, Pseudostaffella, Profusulinella, Wedekindellina, Hemifusulina, etc. are not present in the upper division. Only Fusulina and Fusulinella continued to exist during the upper Carboniferous and gave rise to new genera, Protriticites, Obsoletes, Quasifusulinoides Waeringella and Pseudofusulina. Near the bottom of the upper Carboniferous Triticites and Quasifusulinella are more characteristic. Substitution of the Fusulinidae family by the Schwagerinidae family at the boundary between middle and upper Carboniferous is universally traceable and is the best defined threshold in fusulinid evolution during the entire time of existence of that group.

Thus, development of foraminifera during the Carboniferous shows three distinct stages, substantiating the three-fold subdivision of the system.

Rugose Corals. These also show evidence of three stages of evolution corresponding to three divisions of the system.

The lower Carboniferous is characterized by numerous representatives of colonial rugosae: Lithostrotion, Londaleia, Aulina, Lithostritionella, Nemistium, Diphyphyllum. Representatives of the family of Clisiophyllidae are common among single corals. The flourishing of Dibunophyllum and Caniophyllum and of some Caninia groups is particularly typical.

The middle Carboniferous complex of rugosae is characterized mainly by development of single-coral genera: Bothrophyllum, Jakowleviella, Caninia, Caninella, Caninophyllum, Timania, Pseudotimania, Campophyllum, Meniscophyllum, Stepophrenis, Lophophyllidium Pseudobradyphyllum, Amygdalophylloides, Asophyllum, Carcinophyllum.

Donophyllum, Petalaxis and others are typical colonial forms.

The Rugosae complex of the upper Carboniferous is much poorer compared to older complexes. Massive colonial forms of Lonsdaleiostraea and Cystophora, larger single forms of Caninia and Caninophyllum, and various single forms of Cyathoxonia, Lophocarinophyllum, Axonophyllum, etc. are

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[4] According to the latest data, first species of genera Ozawainella and Schubertella appeared in some localities during Early Namurian time. Thus, some species of these genera were found in Cravenoceras strata on eastern slopes of the Ural Mountains near Shartym River.

characteristic of it. The adaptability of these complexes, indicative of uninterrupted evolution of rugosae through the entire Carboniferous, as well as good definition of individual complexes points again to the undoubted existence of three divisions.

Brachiopods also had three definite stages of evolution during the Carboniferous, which verify the correctness of three-fold division. The complex and peculiar early Carboniferous stage included the following forms which flourished and increased in numbers of species: Spirifer s. Str., Sp. tornacensis, Sp. trigonalis, Sp. striatus, Sp. bisulcatus and Sp. duplicicostus and the following prodictid genera, which appeared at the beginning of the Carboniferous: Dictyoclostus, Pustula, Buxtonia, Echinoconchus, Productus (sensu stricto) Linoproductus, etc.

During Visean and Early Namurian time, such typical productid branches as Gigantoproductus and Striatifera developed. Gigantic chonetids were also characteristic.

Somewhat below our boundary between the Namurian and Bashkirian stages, i.e., in the lower part of Namurian B, a significant qualitative change occurred in the brachiopod complex. Productids, which played the leading part in the early Carboniferous fauna were partly replaced by spirifers during the middle Carboniferous. Choristides among these last replaced Spirifer as a leader.

However, even the productids had a number of typical representatives during the middle Carboniferous, particularly in genera: Linoproductus, Dictyolclostus, and Marginifera. The new genera Alexenia and Kutorginella appeared.

The boundary between middle and upper Carboniferous was signalled by extinction of numerous middle Carboniferous elements, particularly of most choristites. The brachiopod fauna developed new forms at the same time.

Representatives of Camarophoriidae, Dielasmitides and similar forms acquired some importance for the first time in the brachiopod complexes.

Productids and several other families began to develop, rapidly producing many new types in the fauna of the upper Carboniferous. Many of these new genera would reach their best development only during the following early Permian. Among these are Waagenoconcha, Muirwoodia, Urushtenia, Teguliferina and other productids and also the first representatives of the Lyttoniidae family, Sprifeerella, Neophricodothyris, etc. among spirifers or Wellerella, etc. among rhynchonellids.

Thus, despite the continued survival of some groups, the upper Carboniferous complex of brachiopods had undergone a substantial change.

Ammonoids. Evolution of ammonoids was comparatively slow during the first half of early Carboniferous, up to the middle of Visean time. However, beginning with the middle of the Thurnean representatives of Goniatitidae, the most typical family of the early Carboniferous appeared and quickly developed to their fullest.

During late Visean the formation of new types underwent a new spurt of growth. Considerable change in composition of the ammonoid complex occurred at the boundary between the Visean and Namurian stages. At the same time, the Goniatitidae family began to die out. Even such typically Visean genera as Prolecanites, Pronorites and Girtyoceras became extinct. At the beginning of the Namurian several characteristic families which continued to exist for a long time appeared: Homoceratidae, Agathiceratidae, Berkhoceratidae, Reticuloceratidae. The already existing families produced some new genera. In addition to the evolution of 20 new genera, Namurian ammonoids are characterized by considerable change in shell morphology. Changes in composition of the goniatite complex were relatively small between the Lower (A) and Upper (B) Namuran. The beginning of an important new stage in evolution of Carboniferous ammonoids coincided with the boundary between Namurian and Bashkirian stages which corresponds to the boundary between Namurian B and C, of western Europe. This threshold was characterized by extinction of the following genera: Reticuloceras, Hudsunoceras, Baschkirites, Praedaraelites, and Proshumardites. Especially characteristic is the appearance at this boundary of the Gastrioceratidae family which then continued to exist until the end of the Carboniferous and beginning of the Permian. The Pseudoparalegoceratidae family is also present at this particular stratigraphic level.

During the middle Carboniferous and particularly during the Moskovskiy stage some genera of highly organized ammonoids evolved which then continued to exist into the upper Carboniferous: Prouddenites, Agathiceras, Aktubites, Eoschistoceras, Wellerites. This smooths somewhat the ammonoid transition from the middle to upper Carboniferous. Nevertheless, four new families appeared at the beginning of the upper Carboniferous, including such important families as Thalassoceratidae and Marathonitidae, as well as 19 new species; the evolutionary tempo of some families was speeded up; typically upper Carboniferous genera appeared: Uddenites, Parashumardites, Kargalites, Paraschistoceras and Schistoceras.

In summary, the upper Carboniferous complex of ammonoids was sufficiently typical and defined to justify separation of corresponding strata into a full division of the Carboniferous system.

Flora. Judging by the latest data cited for the southern part of European U.S.S.R., the most distinctive threshold in development of the European land flora occurred in the middle of Visean time. Old elements of the Devonian archaeopteric flora then became extinct. In that region, the Upper Visean flora differs from that of the Lower Visean by omission of some genera of ferns and lycopods. Some genera common to Namurian strata began to flourish. Compositionally, there was very little difference between the flora in strata of Lower and Upper Namurian, A and B, respectively. Species that had appeared during the Late Visean, persisted even into Late Namurian time. In general, flora of the entire Namurian — consisting of A and B — remained quite homogenous. Substantial changes took place near the boundary between the Namurian and Bashkirian stages: in the upper part of C_1^5 suite in Donbass. At that level mesocalamites disappeared, having been replaced by stylocalamites so characteristic of the middle and upper Carboniferous. On a par with these, Sigillarias of the Rhytidolepis group and some other forms appeared. It should be emphasized that the compositional change of flora at the middle of the Visean, characterized by extinction of associated Devonian-Thurnean forms, was not smaller than the previously mentioned threshold between the Namurian and Bashkirian stages.

The upper Carboniferous flora of the southern part of European U.S.S.R. is characterized by the total extinction of lepidodendrons, longitudinally fluted sigillaria and aquatic medulloses. Instead, sigillarias with smooth trunks and woody medulloses appeared. Calamites and cordaites favoring arid environments continued to exist in the upper Carboniferous, and tree ferns predominated. All such changes were brought about by the increasing aridity. Flora developed quite differently on the Angarida territory. There, two essential forms changed during development of late Paleozoic flora: lepidophytic and cordaitic. The lepidophyte flora is characteristic of the lower section in Kuznetsk Basin and is considered to be lower Carboniferous (i.e., Upper Visean to Lower Namurian). Three stages in evolution of the cordaite flora are differentiated, of which only the first belongs to the Carboniferous, corresponding obviously to its middle and upper divisions.

However, the comparison of the upper Paleozoic of Angara with the generalized stratigraphic scheme founded on marine fauna and on European flora is still provisional. It is important to note that the strata of Angara lack members which carry a typical early Carboniferous (Thurnean to Lower Visean) flora. Therefore, the first stage of development of Carboniferous flora is missing from geologic history here. It is possible that this division of Carboniferous flora into two parts does not depict the actual situation.

It is interesting that the latest detailed data on spore-pollen complexes of the Carboniferous of the Russian platform show rapid changes vertically and persistence laterally. A substantial difference is noted between spore-pollen complexes of the Thurnean and Visean stages. Devonian types of spores predominate in the Thurnean: the group of Archaeozonotriletes Naum. The Visean complex of spores and pollen is similar to those of the middle Carboniferous and differs from those of the upper Carboniferous by predominance of spores of lepidophytes, calamites and, to a certain extent, of cordaites and pteridosperms.

Composition of upper Carboniferous spores and pollen differs radically from that of the Visean or of the middle Carboniferous, pollen of the type Reticulineae predominating among pteridosperms and pollen of ancient conifers appearing. Pteridophyte spores occur in the upper Carboniferous only sporadically.

Boundaries of divisions and stages of the Carboniferous, as determined by spore-pollen complexes, practically coincide with those determined on a faunal basis.

Thus, Carboniferous spore-pollen complexes of the Russian platform substantiate very well the partition of this system into three divisions.

CONCLUSIONS

The probability of there being three major stages in evolution of the stratigraphically more important groups of organisms during the Carboniferous is definite. It is true that boundaries between these divisions do not everywhere coincide in time when determined by different groups of organisms. Nevertheless, the system's three divisions, corresponding to major stages of development in the organic world, are very evident. Some investigators believe that the biostratigraphic boundary between the lower and middle divisions is sharper than the boundary between the middle and upper Carboniferous. In their contention, they usually cite the development of land flora and ammonoids.

Although such a view may be justified to

Typical Subdivisions: Division	Typical Subdivisions: Stage	Moscow Basin	Don Basin	Western Europe	North America
Upper (C_3)	Orenburgskiy	Pseudofusulina horizon	Cupriferous sandstone	Stephanian stage	Virgilian
			Araucaria suite (P)		
	Gzhel'skiy	Gzhel'skiy horizon	D		Missourian
		Kasimovskiy horizon	N_{3-5}		
Middle (C_2)	Moskovskiy	Myachkovskiy horizon	$M_{4-10}+N_{1-2}$	Westphalian stage: D	Desmoinesian
		Podol'skiy horizon			
		Kashirskian horizon	$L \pm M_{1-3}$	Westphalian stage: C	Atokan
		Vereyskiy horizon	K		
	Bashkirian	Top of Bash-kirian horizon	J	Westphalian stage: B	Morrowan
			$G+H$	Westphalian stage: A	
		Vysokovskiye continental measures	$E_{8-9}+F$	Namurian stage: C	
Lower (C_1)	Namuran		E_{1-7}	Namurian stage: B	
		Protvinskiy horizon	$C+D$	Namurian stage: A	Chesterian
		Serpukhovskaya suite	$B(C_1^v g)$	Visean stage	
	Visean	Okskaya suite	A: $C_1^v f$		Meramecian
		Tulskiy horizon	$C_1^v e$		
		Coal measures	$C_1^v c+d$		
			$C_1^v a+b$		Osagean
	Thurnean		$C_1^t d$	Thurnean Etroeunot zone	
		Cherepetskiy h.	$C_1^t c$		Kinderhookian
		Upinkiy horizon	$C_1^t b$		
		Malevskiy h.	$C_1^t a$		
		Ozvosko-Kohodan strata			

Tabulation of some Carboniferous sections.
Compiled by L.S. Librovich and D.L. Stepanov.
Hatched areas indicate discontinuities.

a certain extent in so far as these two groups are concerned, this circumstance alone cannot serve as a basis for drawing a systemic or sybsystemic boundary. In the first place, as mentioned earlier, the sharpest change in the flora of the European type occurs within the Visean stage, whereas the most extensive renewal of marine fauna, particularly ammonoids, took place in the Namurian and Bashkirian ages. On the other hand, the changes in the composition of the flora at the above-mentioned boundary cannot be compared in scale to the changes in the terrestrial flora that occurred at the boundaries between the Middle and Upper Devonian or the Lower and Upper Cretaceous. The changes in the composition of the marine fauna at the boundary between the lower and middle Carboniferous are also essentially smaller in magnitude than those within the Devonian system, such as at the boundary between the Middle and Upper Devonian. Finally, as was noted above, such stratigraphically important groups as foraminifera and brachiopods at the boundary between the middle and upper Carboniferous undergo a renewal no smaller in magnitude than that at the boundary between the lower and middle series of this system. Hence it follows that the second biostratigraphic boundary within the Carboniferous system, in regard to its scale, does not differ in principle from the first. Thus both can be regarded as boundaries between major divisions of the Carboniferous system.

It is not within the scope of this report to dwell on the features characterizing the fundamental divisions of the Carboniferous system and the stages within these. We may note merely that the Tournaisian stage is taken to include the Etroenian zone, and that the Visean is considered to include its generally accepted range (see table). The Namurian stage is taken by Soviet geologists to include approximately its original range, corresponding to the "Namurian A" and "Namurian B" of Western Europe. Considered in this sense, the marine fauna and terrestrial flora of the Namurian stage are very close in composition to those of the Visean stage, so that the majority of Soviet stratigraphers assign the Namurian stage, in the above definition, to the lower division of the Carboniferous. The "Namurian C" of the Western European stratigraphic scheme, which was included within the Namurian stage at the first Heerlen meeting, because of its essential renewal of marine fauna and flora belongs to the middle division of the Carboniferous and is thus included within the Bashkirian stage. The latter corresponds, in Western Europe, to the "Westphalian A and B" stages as well as to the "Namurian C". The "Westphalian C and D" belong to the Moscovian stage, the sub-triticites beds containing Protriticites and the fusulinid zone with Triticites to the Gzhel'skian stage, and the Pseudofusulina zone to the Orenburgian stage. The Autunian stage of Western Europe has its chronological analogue in the U.S.S.R. in the strata of cupriferous sandstones containing Callipteris conferta Brogn. in the Donets Basin. The latter directly underlie the beds containing Schwagerina in the limestone-dolomite series. Moreover the age of the cupriferous sandstones, and hence that of the Autunian beds, may correspond to the upper part of the Orenburgian stage in the upper Carboniferous and to the bottom of the Schwagerina beds in the Sakmarian stage.

These subdivisions of the Carboniferous system, down to the level of the stage inclusive, may be distinguished, at least on the basis of marine fauna, within the areas of the various continents and perhaps on a planetary or almost planetary scale as well.

QUESTIONS OF TAXONOMY AND NOMENCLATURE OF FOSSIL POLLEN AND SPORES[1]

by

Ye. D. Zaklinskaya

In referring to problems of taxonomy and to the nomenclature of fossil pollen and spores, I wish to call the attention of investigators to those unsolved problems of palynomorphology and of spore-pollen analyses which currently hinder their use in paleobotanic as well as in stratigraphic studies.

Many works on questions of nomenclature and taxonomy have been published, mainly abroad. They deal also with the closely related problems of the classification of pollen and especially of "dispersed spores." I am not in a position to review their contents in this paper. I shall only refer to the fundamental ideas recently brought up by various authors. I shall, however, express my own opinions on taxonomy and the rules for a correct denomination of fossil pollen and spores.

The starting point for a correct description and denomination of vegetable remains, and consequently of pollen and spores (rather their spore cases or sporangia), is centered in the International Regulations of Botanic Nomenclature, where special recommendations concerning pollen and spores occur.

A large body of material arising from these regulations, and applicable to fossil pollen and spores, is brought up in a series of recently published works by R. Potonié [19, 20]. It is, of course, fully utilized in this communication.[2]

In connection with the broad development, during the past two decades, of the paleobotanic technique known as spore-pollen analysis, many authors isolated a large number of new forms which required determination and attribution to some system. These authors solved these problems by various means, basically without regard to the International Rules of Botanic Nomenclature. In particular, they ignored the method of models, which resulted in an irresponsible multiplication of the number of genera and species.

Because spore-pollen analysis was mainly developed in the course of geologic and geographic investigations, most of the specialists involved in this aspect of paleobotany were not biologists. Quite naturally, many investigators were thus not sufficiently informed about the basic rules of botanic nomenclature during the early years of the development of spore-pollen analysis. Nor could a uniform approach be perceived in foreign authors' works in this field. This is to be expected as a result of the lack of world-wide agreement on contemporary fossil pollen and spore classification.

However, even the new cadres of spore-pollen analysis specialists originating from within botanic circles ignored the International Code Rules.

The lack of a unique system of classification and of uniform rules of fossil pollen and spore nomenclature resulted in a series of disagreements. The absence of literature on fossil spore and pollen and of a collection of standardized geno- and holotypes, and the ignorance of priority rules and the poor knowledge of foreign literature were the cause of many incompatibilities in natural systems and generic designations, such as Alnipollenites, Alnites, Myrtopites, Myrtaecites, Myrtaedites, Myrtopollenites, Myrtipites, Eucalyptoidites, Eucalyptoides, Quercoides, Pinites, Cedripites, etc..., together with the clearly morphographic Extratriporopollenites, Tricolporites, Tricolpites, Triorites, etc... Most appear incorrect on the basis of the rules. The position of each genus within the taxonometric series is not clarified, and has a particular suggestive significance, merely pointing to some morphologic analogy with

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[1] Voprosy taksonomii i nomenklatury iskopayemykh pyl'tsy i spor.

[2] The full translation of the last nomenclature Code, as accepted by the Eighth International Botanical Congress of Paris in 1954, has been issued (Translation by Ya.I. Prokhanova, under the edition of B.K. Shishkin and I.A. Linchevskiy. Izd-vo Akademiya Nauk SSSR, 1959).

present-day or fossil pollen and spores. All this results in the impossibility of making any comparison with accumulated material.

The scope of the important questions linked with the development of spore and pollen analysis as a branch of paleobotany is very wide. First of all the knowledge of pollen and spore morphology and systematics is required to establish on that basis the most important genera and species which permit the differentiation of sedimentary deposits. It also requires a recognition of progressive transition from an artificial to a natural classification (within accessible limits).

Naturally, it is important that genera and species of dispersed pollen and spores be correctly and uniformly described and denominated. These pollen and spores dispersed in rocks (sporae dispersae) appear to be separate plant organs. They are characterized by complex generic and morphologic criteria, and in most cases are related to contemporary plant pollen species.

When denominating and describing these plant remains, it is important that the International Regulations of Botanical Nomenclature worked out in 1950 during the Seventh International Botanical Congress of Stockholm be adhered to. Chapter PV2 of these recommendations states that "the fundamental rules applicable to the denomination of contemporary plants are also applicable to natural as well as to form-genera of fossil plant remains."

What do the ideas of "natural" or "form" genera really mean? The former emerge as "taxa" of natural classification, and they may be isolated either on the basis of a whole plant, which is basically related to the contemporary flora, or on the basis of its separate organs, or of their aggregate (leaves, wood pulp, seeds, fruits, fruitings, microspores, etc...) fundamentally related to fossil plant remains.

For the genera identified by separate plant organs, the idea "organ-genera" is anticipated by the international regulations, which recommend the designation of the specific organs by which these genera were denominated.

Form genera appear to be taxa, and to some degree artificial and subordinated to the so-called morphographic system. Form genera are used in the classification of fossil plant remains which lack sufficient criteria pointing to their natural position, but for which, to quote the regulations, "a binomial denomination must, for practical purposes, be applied."

Form genera may include species belonging to different families and even to higher-rank taxa, and they may be determined as the remaining form taxa as diffused microspores. The morphologic similarity of microspores and of natural taxa has not been demonstrated as yet, but in many cases their genetic linking with the natural system high-ranking taxa is assumed.

In accordance with botanic nomenclature regulations, the natural and form-species denominations (including organ species) must be made according to binomial nomenclature, but each of the new genera or species must belong to a type, respectively, holotype or genotype.

Thus, in our opinion, a solution must be found to the question of the correct description, denomination, classification, and, as a result, the establishment of the taxonometric rank of fossil pollen and spores.

However, until now there has been no uniform opinion either among foreign or our own palynologists, as to whether fossil pollen and spores should be considered, as such, plant organs, on whose studies organ genera, or their correct relationships to form taxa in general, may be ascertained.

The fact is, that part of the fossil cases of microspores and spores, mostly those of Paleozoic and Mesozoic origin, cannot be linked with contemporary plants, since they are related to extinct species (or genera). Some microspores, namely those of Kaynozoysk age, disclose an obvious morphologic similarity with pollen and microspores from contemporary plants.

This results in the necessity for classifying the more ancient pollen and spores by a particular morphographic system, whose taxonometric frame is not compatible with that of the natural system (for lower rank taxa, in any case).

At the same time, the clearly expressed morphologic similarity of the upper Mesozoic and Kaynozoysk forms with contemporary ones promises great possibilities for their classification within the framework of the natural system, and the identification of the taxonometric units for fossil pollen and spores with the natural taxa system. There also results a somewhat simplified approach to the identification of new species without marking, which was done for pollen, and tendency of an unlimited extension of the natural genus without suitable foundation.

Disputative works along these lines still are lacking in palynomorphologic literature. However, two basic trends have lately been

observed in the determination of new species. These came to light upon reviewing the lists of fossil pollen and spores in stratigraphic works and in the monographs devoted to their description.

Certain researchers strive to relate the fossil forms to the natural system, and to denominate as species all their form varieties, without sufficient basis. This accounts for the appearance of such species as Eucalyptus menneri Bolch., E. colorata Bolch, and numerous others [1]. Other workers, to the contrary, definitely renounce the natural system and believe such forms to be taxa, which would be more proper to relate to natural genera, for example species Dipterella f. typica sp., and f. nov., clearly corresponding to the genus Podocarpus [2].

Finally, a third group stands in a "happy medium," and limits the determinations to natural genera or families (Quercus sp., Tilia sp., Nyssa sp., etc..), ignoring the necessity of isolating new pollen and spore species or forms.

But what basic trends are there among foreign palynologists and specialists of spore pollen analysis? Perhaps the great majority is of the opinion that the dispersed microspores must be related to form taxa. G. Erdtman for instance, relates all fossil dispersed microspores and spores to the form-taxa category and proposes for them the denomination "Sporomorfa" (abbrev, Spm.), and subordinates them only to artificial morphographic systems, even in those cases where the microspore and spore relation to natural taxa is evident. G. Erdtman proposes to give sporomorphae species binomial denominations based on the morphographic classification worked out by him [5, 6, 7].

The Van der Hammen [11] classification system of contemporary and fossil pollen is based, for genera, on the number of composing cells and on the position of the germinal apparatus, and for species, on the character of the sculpture (all these are form-genera and species). The majority of authors use as a base, a modified Troels-Smith morphographic system [13].

W.L. Norem [17] proposes for the fossil sporomorphae, a classification and corresponding denomination based on the variations of the structure, form, contour, and sculpture of the germinal apparatus. His classification anticipates difficulties and limitations between the "monowrinkle" microspores and the "monocicatrized" spores, and also the microspores with triradial sign, and the triradial spores.

In his last works, W. Krutzsch [14] generally tried to merge fossil spores and pollen in broad groups not belonging to the Botanic Nomenclature Regulations, but in his earlier works [15] he was inclined just as was P. Thompson and H.D. Pflug [21], to adhere to the morphographic classification system, and to relate sporomorphae only to form taxa. Judging from the latest works of R. Potonié [19, 20], and from his statement at the Geerlensk symposium on the stratigraphy of coal deposits, he is much opposed to the irresponsible attribution of sporomorphae to natural taxa.

Other authors, such as K. Facgri [9, 10] admit the attribution of a series of dispersed pollen and spores to natural taxa, whenever the morphologic peculiarities permit their comparison with contemporary living plants' pollen and spores. At the same time, considering such a solution as a compromise they recognized that, theoretically, all dispersed spores must be related to the form-taxa category [3, 9].

It seems to us that in the solution of this question the genus should be taken as the fundamental taxon for the fossil flora. With the exception of comparatively recent material capable of showing the relation of the fossil form to a natural system, pollen and spores may be used more profitably than any other plant organ, as a basis for genus determination.

Contemporary systematic palynology (G. Erdtman's works) has shown that in many cases natural systematics may be corrected by means of a careful study of pollen morphology. But, naturally, the deeper the penetration into the historic past, the less our conceptions of the rank and volume of taxonomic units coincides with their rank and volume in contemporary flora.

The generic similarity of the upper Paleogene, Neogene, and contemporary plants is obvious, and there is no necessity for creating form genera for this range of flora. The Oligocene pollen Alnus must be called just that.

It is necessary to introduce the form taxa (species, genera, groups, etc.) for the lower Paleogene and Upper Cretaceous flora. Together with such forms indeterminable by the natural system, a series of species and genera, unquestionably belonging to natural families, and having an obvious morphologic resemblance with contemporary genera and even species, are revealed in these and in older deposits.

Taking into account the deep stratigraphic position of such findings, it is pertinent to isolate the organ taxa. In naming species of such dispersed microspores, the generic

denominations must point to their origin. The organ genus Alnites (pollen) indicates its relationship to the genus Alnus Dietr. (even its identity is possible), and its relationship to the Betulaceae family.

In studying most of the Mesozoic (Jurassic, Triassic), and particularly the Paleozoic forms, we nearly completely depart from the natural system (in any case, within such taxa range as species, genera, and even families). Here we are temporarily compelled to adhere to form taxa, whereas the binomial species must be composed of the form genus and the trivial name based on the grain's morphologic peculiarities (Triorites horrasi Couper, Leiotriletes Naum, etc. [10]. According to the Regulations, the form species are grouped into form genera, and are subordinate to the types regulations. The additional form-genera grouping is achieved outside of the rules of botanic nomenclature, and they are correspondingly not subject to priority rules (see table).

The form taxa "turma" by R. Potonié [19], the D. Pant's "groupp" [4], the H. Flug's "stemma" [18], the S.M. Naumova's "group" [16], and the higher taxonomic ranks are indispensable for the systematization of the fossil material. In the course of the investigation process, these taxa may change, split, or join by various means. The possibility of transference of different form taxa into the natural system is not excluded. Such is, for instance, the case when spore carriers are found containing forms of dispersed spores already studied. In such cases the spore denomination supersedes that of those generative organs, according to the Rules.

When denominating the organ genera (not species!), the International Regulations recommend the indication of the organ after which that genus was determined, by adding such terminations as "pollis", "spora", "pollinites", "sporites" etc. From our viewpoint, it would be in all cases more correct to indicate the organ (whether the genus or species) by adding to the general denomination the words "pollen", "spora", or "spm" (the latter relating to form taxa), rather than to have recourse to terminations. This would avoid an artificial broadening of the genera (or that of other taxa) when compiling the general lists of fossil flora determined by means of various organs.

Let us review certain examples of fossil microspore denominations taking into account their greater or lesser similarity to contemporary-plant microspores.

1) In the aggregate of its morphologic criteria, the microspore belongs to the natural genus by comparison with contemporary-genus species. This may be demonstrated by comparison with recent standard material. It spreads over a comparatively small number of genera and species, whose counterparts of contemporary spores and pollen have been well studied, and are well endowed with characteristic morphologic criteria. Most reliable findings of species and genera similar to the contemporary ones are usual among complexes of Quaternary and Tertiary flora. For example, Alnus pentaporina sp. nov. (pollen), A. rugosaeformis sp. nov. (pollen) belong to the natural genus Alnus Dietr. Alnus rugosaeformis sp. nov. (pollen) is close to the natural genus Alnus rugosa (Du Roi) Sprg., possibly even belonging to it, a fact which may be demonstrated in the course of further investigations. Alnus pentaporina and Alnus rugosaeformis belong to the natural categories.

2) However, the microspore disclosing, by most of its criteria, a close resemblance with the microspores of natural, actually-living genera, is identified with Paleogene and Upper Cretaceous deposits. By comparing the fossil form with standard material, most of the criteria permit its comparison with species of the natural genus, and its unconditional inclusion in a natural family. Such a microspore must be related to the natural system and the organ genus must be identified after it. In its designation, the natural similarity to the actually living genus must be indicated. At the same time, it would be proper to use as a basis the genus denomination, and to modify it by means of the termination "ites", as has been customary in national palynology, and in accordance with G. Erdtman's proposals. Thus, Alnites org. gen. nov. (pollen) or Dacrydiumites org. gen. nov. (pollen) definitely indicate that these are natural taxa related to the Betulaceae and Podocarpaceae.

Such genera will be real only when, during their description, types of genera are given, microphotographs or well-drawn sketches are provided, and all rules of rating, foreseen by the International Regulations, observed. The species of Alnites, Dacrydiumites, and other similar organ genera are binomial according to the Regulations, and they must have the genus type, for example Alnites globulosa sp. nov. (pollen).

In the case, when a species similar to one described has been previously differently named, and its denomination made in accordance with the morphographic artificial classification, there is a legal right to indicate the form in the natural genus, identifying it with our genus and species, and nullifying our former appellation after showing this in the synonomy.

It is not meant to juxtapose our Alnites

Outline of the Relationship between Natural and Artificial System Classifications

				Example in accordance with the Classification by S.N. Naumova and other authors		
Division	Psilogena	Psilogena		Polina (Naum)	Naum. (group) Triletes	Forma, form. sp., form gen., stemma, turma, subturma, group, etc.
Subdivision	Pteropsida	Pteropsida				
Class	Angiospermae	Angiospermae		Porosa (Naum) (group)		
Subclass	Dicotyledones	Dicotyledones	Normapollis Pflug (Stemma)			
Order	Fagales	Fagales		Pentaporosa (Naum)		
Families	Betulaceae	Betulaceae		Subgroup (Form. gen.) ?	Leiotriletes' (I Br) (form. gen.) Subgroup	
Genus	Alnus Dietr.	Alnus Dietr. / Alnites gen. nov. [pollen]	Plicapolis form. gen.	Ptychopentaporina (Naum) forma ?	Leiotriletes microugosus (I Br.) Naum. ? (forma)	
Species	Alnus rugosa (du Roi) Sprg.	Alnus aff. rugosa (du Roi) Sprg. / Alnus pentaporina sp nov [pollen] 1 = ? Alnus rugosa] / Alnites pentaporina sp. nov. (pollen)	Plicapollis pentaporina form. sp.			
Systems of classification	Natural		Artificial			
Taxa after the fossil remains	→	Organ-taxa	Form-taxa			
Degree of dependence on the Botanic Nomen. Regs.	Submit to Rules of Botanic Nomenclature			Taxa above genus do not submit to the Rules of Botanical Nomenclature		

globulosa sp. nov. (pollen) with Alnipollenites R. Pot. since the latter is not a natural category. Pollenites R. Pot. appears to be a form taxon, standing over the genus, and only having dubious relation with the natural categories. As to the denomination "Alni", it has indeed only an indicative significance, pointing to the resemblance of the form discovered by R. Potonié with contemporary species of Alnus pollen.

The microspore discovered in the pre-Quaternary deposits (particularly Mesozoic and older ones), and not having complex morphologic criteria permitting assignment to a location within the natural system, must be related to form taxa. A form genus may be assigned to it, and correspondingly a form species, in accordance with the Regulations. The denomination of such genus and species must be given according to the monographic, artificial classification. It must not, however, reflect its proximity to the natural taxon, so as to avoid confusion when further interpreting data of pollen and spore analyses.

Thus, it is not proper to consider Castaneites as a pollen, having a remote resemblance with Castanae pollen, especially so since pollen of the contemporary Castanea genus is still little known, and it has a similarity with numerous morphologic analogues among a large number of genera of various families. The denomination Tricolporites castanaeoides is more acceptable because the appelation of this form's genus shows that it is related to form taxa, and that therefore the trivial name "castanoides" only emphasizes the morphographic resemblance with a pollen similar to the contemporary genus Castanea.

The denomination Leiotriletes roburatus is also acceptable as a form taxon. According to the Regulations, Leiotriletes is a form genus, and that is why its individualization requires the observation of the type rules, i.e., Leiotriletes form gen. nov. must have the type of the genus. In cases where the conception of Leiotriletes or Saccites in the process of the artificial classification system's remaking already embraces much broader conceptions than genus, and corresponds to a higher-rank taxon (similar to Triletes, Monoletes, Pollenites, i.e., turma group, stemma etc..., which unite artificial (form) genera), then priority rules do not apply, and the individualization of the type is not compulsory.

The form genera cannot be included in natural families, or united in a family named after the genus' denomination by means of adding the termination "aceae". Their supposed kinship with various natural system taxa may be urged in the text, while suggesting the genetic links.

The question as to which of the known morphographic classifications one must adhere to, when describing and denominating new fossil spore and pollen forms, in answered only by practice. The Naumova's classification, currently modernized by a group of authors, is apparently the most appropriate for spore classification. For gymnospermae and angiospermae the Torels-Smith classification [13], modified by N. Pflug [16] is the most acceptable for the pollen group with triple or multiple compartment germinal apparatus, and with preserved traces of the triradial cicatrix.

At the present time we are not in a position to compel all investigators to adhere to either of these classifications. The appropriate recommendations may be worked out during an All-Union Conference, and then presented for appraisal to the Botanical Congress. But, it is absolutely indispensable that each school of investigators selects, once and for all, a totally acceptable classification from their viewpoint, and that all individualized new forma and genera be monotypically classified, in the denomination given the form or a group of forms.

To conclude, it is pertinent to note, that since our present-day knowledge of the morphology of contemporary plant pollen is still lagging, it is not advisable to attempt to determine, by a natural system all the fossil pollen and spores through genera and species. This is not necessary and is actually impossible as yet without leading to a great number of errors. The external resemblance of pollen and spore cases found in fossil state and unrealistically utilized to prove natural links, leads to an accumulation of unsatisfactory denominations, such as Eucalyptus menneri, Protoquercus, Myrtoidites, etc., which, in reality, have nothing in common with the genera shown in the denominations. It is better to refrain from mentioning the natural links in the denomination, and to rather relate such species to form taxa. As to the textual division, it is better to constitute one's own considerations as regards the possibility of a generic link of these fossil forms using the criteria of microspores and spores of contemporary genera or species.

As our knowledge of contemporary and fossil spore and pollen morphology broadens, many form genera and species may find their own place in the natural system.

It is quite clear that the time has come when it becomes indispensable to establish an interdepartmental, coordinating, and continuously functioning commission on taxonomy

and nomenclature of dispersed pollen and spores. Aside from purely organizational work in the indexing of new species, its terms of reference should include the drafting of special instructions containing the basic recommendations concerning the description, documentation, taxonomy, and nomenclature of fossil dispersed spores and pollen in accordance with the Regulations.

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ON THE STRATIGRAPHY OF THE PRECAMBRIAN FORMATIONS IN NORTH KOREA (THE PROVINCES OF RYANGAN AND SOUTHERN KHAMGEN)[1]

by

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This article deals with the lower Proterozoic formations of the geosynclinal type, known as the Machenren series, which are developed in the provinces of Ryangan and Southern Khamgen. These are divided into three suites: the Sonzhin, Puktechen and Namdechen suites, as well as the deposits of the Sinian system.

Some data on the structural position of the Precambrian formations in the northern part of Korea are presented in conclusion.

* * * * *

Precambrian formations are widespread in North Korea, extending over the large area of the southern end of the so-called Eastern Manchurian massif, which projects beyond the Korean border into the territory of Northern China [9].

The earliest references to the Precambrian rocks in North Korea are to be found in papers by Japanese geologists, such as S. Kavasaki, I. Kinosaki, S. Nakamura, I. Tateiva [2, 3, 7] and others, who began to study the geology of this territory more than twenty years ago. Within the Precambrian rocks of Korea, in addition to the Sanvonian system, which is analogous to the Sinian of China, the Japanese geologists distinguished:
a) a series of ancient metamorphic rocks and
b) the granites and granite-gneisses that intruded them. The metamorphic rocks were divided further into the Machenren, Okchen and Renchen systems, each named after the area in which it is developed. These "systems", however, are not stratigraphic units and each of them combines rocks of different ages, composition and origin, so that to call them systems is, in the present writers' view, incorrect.

Within the area of the provinces of Ryangan and Southern Khamgen, the Precambrian rocks are known as the Machenren system. I. Kinosaki [3] has suggested that they be subdivided as follows (from bottom to top):

1. Mica schists, gneisses, limestones and dolomites; 1,500 meters;

2. Dolomites with interbedded magnesite; 3,000 meters;

3. Dolomites and limestones; 1,300 to 3,000 meters;

4. Mica schists; 1,200 meters;

5. Quartzites and feldspar schists; 400 meters.

The age of the rocks in the Machenren system was said by I. Kinosaki to be Precambrian.

The granites and granite gneisses are widespread in the provinces of Chagan and the western part of the province of Southern Khamgen. These rocks, in the opinion of S. Nakamura, I. Tatieva and others, although they resemble the Archean gneisses of Northern China and Manchuria, cannot be included in the Archean, inasmuch as they show intrusive contacts with the ancient metamorphic rocks (of the Machenren system).

The area of North Korea began to be studied in 1945 by Korean and Soviet geologists, including Pak Son Uk, Li Dze Kha, V.I. Biryukov, I.S. Vasil'yev, L.V. Klimov, A.T. Solov'yev, Pak Un Gen and others, who further elaborated the stratigraphy of Korea and continued to study its mineral resources. Nevertheless, in spite of the fairly long period during which such studies have been made, many very important problems of the geologic structure of Korea have still been little studied. Foremost among these is the stratigraphy of the Precambrian rocks and the subdivision of the igneous and many other rocks.

[1]K stratigrafii dokembriyskikh obrazovaniy Severnoy Korei (provintsii Ryangan i Yuzhnyy Khamgen).

An important step forward was made by the investigations of the present writers' expedition,[2] which in 1956 carried out a systematic survey on a scale of 1:200,000. Some of the results of this work, regarding the stratigraphy of the Precambrian, are the subject of the present article.

According to our observations, the Precambrian formations in the provinces of Ryangan and Southern Khamgen, which make up the single Machenren series, may be divided into the following suites (from bottom to top):

a) the Sonzhin: gneisses, granite-gneisses, amphibolites, schists and marbles; 3,000 to 4,000 meters;

b) the Puktechen suite: crystalline limestones and dolomites; 5,000 to 6,000 meters;

c) the Namdechen suite: schists, quartzites and crystalline limestones; more than 2,000 meters.

The rocks of the Machenren series are unconformably overlain by Sinian deposits consisting of conglomerates, quartz sandstones, argillites, clay shales, limestones and dolomites. The Sinian deposits are up to 1,920 meters thick.

In addition to the above-mentioned groups of rocks, the provinces of Ryangan and Southern Khamgen also contain widespread Archean granitoids. Lower Proterozoic, Paleozoic and Mesozoic intrusives are also known.

In the northern part of the territory under consideration there is a considerable development of Mesozoic and Cenozoic lava flows.

[2] The Soviet geologists Ye.V. Golota, K.B. Il'yin, I.N. Luk'yanov, A.A. Mezhvilk, V.K. Putintsev, S.Ye. Sinitskiy and others participated in the work of this expedition.

THE SONZHIN SUITE

The Sonzhin suite[3] occurs mainly in the province of Southern Khamgen, but also in the eastern and southeastern parts of the province of Ryangan. It underlies the carbonate deposits of the Puktechen suite, usually cropping out in the cores of anticlines or as tectonic blocks squeezed out between other Precambrian rocks and the intrusive formations. The most extensive exposures of this suite, amounting to several tens of square kilometers in area, have been found on the left bank of the Puktechen River, southeast of Khapsu, west of Pukchen and in a number of other places.

The suite is composed predominantly of amphibolites, gneisses and granite gneisses; marbles, eclogites and schists are less abundant. The internal structure of the suite is most clearly seen in the area northeast of Dzyngsanri. Here the rocks are exposed in the cores of anticlinal folds composed of the crystalline limestones and dolomites of the Puktechen suite, covering an area of some 40 to 45 km^2. Biotite-amphibole gneisses and biotite-amphibole granite-gneisses predominate in the lower part of the suite; the upper part is made up of various amphibolites, schists and marbles. A similar composition is found in the Sonzhin deposits, developed east of the Kwanchen mine, southeast of Khapsu and in a number of other places. According to observations by Ye.V. Golota, the broad zone of rocks of the Sonzhin suite in the valley of the western Namdechen River is also clearly divisible into two members. The lower member here

[3] The name of this suite is derived from the former name of Mt. Kim Chak, in the vicinity of which it forms extensive outcrops. Here and in the remainder of this article the geographic names will be given in the transcriptions adopted by the Chinese People's Republic; for some of them, synonyms used on maps published in the U.S.S.R. will be given in parentheses.

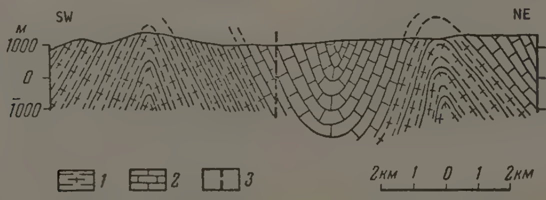

FIGURE 1. Geologic section through the area of the left bank of the Puktechen River, in the vicinity of the village of Sinbokchan.

1 -- rocks of the Sonzhin suite; 2 -- rocks of the Puktechen suite; 3 -- faults.

consists of gneisses and granite-gneisses and the upper member of amphibolites, schists and marbles. A characteristic feature of the suite is the clear layering of the rocks produced by the interbedding of gneisses, granite-gneisses, amphibolites, marbles, and mica schists. The individual layers vary in thickness from several centimeters to a few tens and even hundreds of meters. The total thickness of the suite is 3,000 to 4,000 meters.

In the lower part of the suite the rocks are usually migmatized; interlayered varieties predominate and ptygmatites are less common. The vein material has the composition of granitic haplites and pegmatites and is irregularly distributed. The thickness of the individual veinlets ranges from several centimeters to 0.3 to 0.4 meter. In some places the migmatization is associated with the contacts of several small granite and granite-gneiss massifs.

A feature of the rocks of the Sonzhin suite that has attracted attention is the boudinage structures, which are widespread in the lower part of the suite among the migmatized rocks. The boudins consist of various amphibolites, and the mass of rock surrounding them is made up of biotite gneisses and granite-gneisses. The shapes of the boudins are lenticular and block-like. In a number of districts were found irregular blocks of migmatized amphibolites enclosed in the gneisses and granite-gneisses. In addition, one encounters structures whose formation was not associated with migmatization: boudins of amphibolites, granites and other formations within carbonate rocks. Such structures occur in the upper part of the suite.

The gneisses of the Sonzhin suite have a banded structure and a uniformly medium-grained, lepidogranoblastic, sometimes relict, hypidiomorphic texture. They are represented by varieties consisting of biotite and of biotite-amphibole. Their mineral composition includes: plagioclase (25 to 28% An), microcline, quartz, ordinary hornblende and biotite, smaller amounts of sericite, epidote, chlorite and carbonate, with apatite, sphene, zircon and magnetite as accessory minerals.

A characteristic feature is metasomatic microcline, as well as the replacement of ordinary hornblende by biotite, and among the secondary processes, chloritization of the biotite and sericitization of the plagioclase.

The granite-gneisses, which are for the most part developed in the lower parts of the Sonzhin suite, consist of biotitic and amphibolitic varieties with a medium-grained, heterogranoblastic or lepidogranoblastic texture and a schistose structure. They are composed of plagioclase (oligoclase), microcline, quartz and one of the dark-colored minerals: either biotite or ordinary hornblende. Apatite, sphene, zircon and ore minerals have been found in them as accessories, and chlorite and sericite as secondary minerals.

The pyroxene and plagioclase amphibolites usually occur in the upper part of the suite as fairly large bands and small lenses. The pyroxene amphibolites, medium- and fine-grained, consist of brown and cinnamon-brown ordinary hornblende (diopside-hedenbergite) and plagioclase; they also contain zoisite, muscovite, sphene, apatite and an ore mineral in small quantities. The pyroxene is sometimes replaced by a pale-green amphibole of the actinolite-tremolite series. The texture is panallotriomorphic and the structure roughly parallel. The plagioclase amphibolites consist of plagioclase and ordinary hornblende, in places replaced by actinolite; biotite, epidote, zoisite and sericite are present as secondary minerals.

When there is a considerable development of secondary processes in the amphibolites, only acidic plagioclase and actinolite are preserved, secondary quartz and biotite appear, and saussuritization is more widespread. The pyroxene and ordinary hornblende encountered in such amphibolites are relict minerals. The eclogites, which occur in small amount in the Sonzhin suite, are of great interest becuase they are found in association with amphibolites, marbles and schists. They consist of light-green monoclinic pyroxene ($c\epsilon = 47°$; $\epsilon - \omega = 0.029$, $2V = +64°$), rose-colored garnet and a very small quantity of epidote, zoisite, quartz and chlorite, forming pseudomorphs after the garnet. The structure is panallotriomorphic and the texture massive.

The pyroxene-containing gneisses, in contrast to those considered earlier, are of subordinate importance and are found only in the upper part of the suite in the form of thin strata. Their mineral composition is as follows: monoclinic pyroxene, tremolite, plagioclase microcline and mica, with quartz, graphite, zoisite, sericite and carbonate present in secondary amounts and rutile, sphene and apatite as accessory minerals. The rocks are characterized by xenomorphic, somewhat elongated mineral grains which usually show no regular faces. Among the processes of metasomatism, the most clearly developed are tremolitization of the pyroxene and the formation of new microcline and mica. More low-temperature secondary processes include sericitization and saussuritization of the plagioclases. When the processes of metasomatism are extensive, particularly amphibolitization, the pyroxene-containing gneisses are frequently altered to

tremolite-actinolite schists often considerably enriched in graphite. Such schists occur in the area of the Machenren Range.

The marbles — massive, medium-grained and large-grained crystalline, white and light gray — consist of isometric polysynthetic twinned grains of carbonate ranging from 0.4 to 1.5 millimeters in size. The skarns, in addition to carbonates, contain variable amounts of monoclinic pyroxene, tremolite, epidote, zoisite, scapolite, phlogopite, plagioclase, quartz and sometimes microcline and apatite, sphene and an ore mineral as accessories. These marbles occur in the form of thin interbeds and lenses in the upper part of the Sonzhin suite.

The crystalline mica schists form small layers up to a couple of hundred meters in thickness, and frequently associated with the marbles; they consist of albite, dark mica, graphite, and small amounts of muscovite, carbonate, apatite, rutile and zircon. The graphite, which forms 10% or more of the rock, forms plate-like grains distributed more or less evenly throughout the rock.

The rocks of the Sonzhin suite are considerably metamorphosed. Most of them are characterized by mineral associations (ordinary hornblende, medium and acidic plagioclase, microcline, etc.), indicating a moderate degree of regional metamorphism. The presence in certain rocks (pyroxene-containing gneisses and pyroxene amphibolites) of monoclinic pyroxene and brown ordinary hornblende testifies to their alteration under relatively high-temperature conditions. The presence of eclogites in association with amphibolites, marbles and gneisses, of course, may perhaps indicate that the eclogite association of minerals arose earlier, under the conditions of a high degree of metamorphism, in contrast to the associations of minerals in the surrounding rocks. Apart from those mentioned above, certain rocks contain associations of hydroxyl-containing minerals — epidote, chlorite, zoisite, actinolite and others — indicating lower degrees of metamorphism.

In the lower part of the suite, as already mentioned, the rocks are migmatized. A study of the boudinage structures in the zone of migmatization suggests that the migmatization of the rocks was at least a twice-repeated process. Among the metasomatic processes, quartz and calcium metasomatism must be mentioned; traces of both are observed in the gneisses and granite-gneisses. Calcium metasomatism has resulted in the development of microcline after plagioclase. The quartz metasomatism is later, and is manifested in the formation of new metasomatic quartz. In the upper part of the suite the normal process is amphibolization, reflected in the replacement of the pyroxene by green ordinary hornblende and the latter's subsequent alteration to amphibole of the actinolite-tremolite series.

These deposits as a whole form a varied complex of metamorphic formations of different primary natures. In the case of certain rocks, such as the marbles, the mica schists and the pyroxene-containing gneisses, the primary sedimentary origin is quite clear; this may also be determined for certain amphibolites that are interlayered with the marbles. The greater part of the amphibolites originated in the alterations of basic rocks, as indicated by their preservation in relict igneous structures.

The rocks of the Sonzhin suite were formed mainly under the conditions of regional metamorphism. Metamorphic alterations, as shown by the mineral associations, took place repeatedly, accompanied by the development of metasomatic processes and migmatization. Some of the rocks, such as the tremolite-actinolite schists with graphite, in all probability originated under the conditions of later, superimposed dislocational and post-magmatic metamorphism, as proved by the local distribution of such rocks and their specific composition.

THE PUKTECHEN SUITE[4]

Among the Precambrian formations of the Machenren series, the most prominent are the carbonate rocks that form the thick Puktechen suite. In the center of this region the suite extends from the upper reaches of the Chintonchen and Puktechen Rivers, southward through the areas of the Chonnam and Ponsan Mines, into the basin formed by the middle reaches of the Namdechen River.

On the left bank of the Puktechen River basin this suite composes the Machenren Range and extends from the village of Pekamdong toward Sinbokchang and farther southward to the area east of Dzyngsanri. Smaller areas of development of this suite occur south and east of the village of Pkhogori, south and west of Pegam, in the basins of the Ryusemul' and Unchongdan Rivers and in a number of other places, usually forming outcrops of erosional fensters exposed through the mantle of Cenozoic lava flows.

Study of these outcrops, in which the rocks of both the Sonzhin and Puktechen suites occur, in the areas west of the Machenren Range,

[4] This suite was named after the Puktechen River, which flows into the Japan sea around Tanchen; the rocks of this suite are very widespread in the basin of this river.

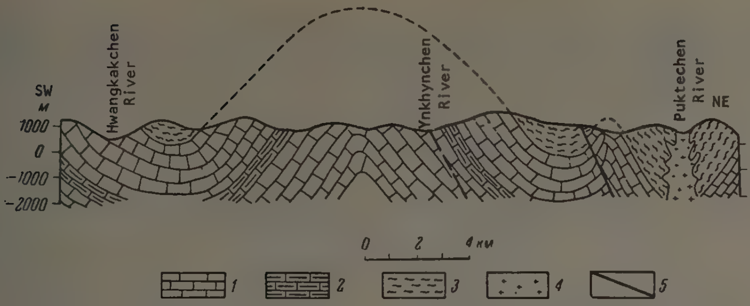

FIGURE 2. Geologic section through the area of the interstream divide between the middle reaches of the Namdechen and Puktechen Rivers.

1 -- rocks of the Puktechen suite; 2 -- series of interbedded marbles and schists in the middle part of the Puktechen suite; 3 -- rocks of the Namdechen suite; 4 -- granites; 5 -- faults.

suggests quite convincingly that both suites are conformable; in the region east of the Machenren Range A.A. Mezhvilk has suggested that in places there is an unconformable contact between these suites.

The Puktechen suite is divided into three conformable series (which may be considered as subsuites): 1) massive marbles, 2) interlayered marbles and schists, and 3) bedded marbles.

A series of massive marble composes the lower part of the suite, which is exposed on the left bank of the Puktechen River, west and south of the Chonnam Mine, on the upper reaches of the Ynkhynchen River, and in a number of other places in the northern part of the region. Massive white, yellowish-white and more rarely light-gray fine-grained and medium-grained marbles are the most widespread here. Often one encounters skarns and varieties that contain different silicate minerals. Dolomitic marbles and quartzites are less widespread. In the upper part of the series the massive marbles gradually merge into banded marbles, among which interbeds of mica schists occur.

The marbles and dolomitic marbles usually have a granoblastic and nonuniform granular structure, and consist of carbonate grains varying in size from several hundredths to one millimeter, and in rare cases up to 2.5 to 3.0 millimeters when they are embedded in a more fine-grained carbonate mass. The grains are isometric and irregular in shape.

The marble containing silicate minerals are most widespread in the southeastern part of the region, in the form of lenses and layers ranging in thickness from several meters to several tens of meters, and consist of variable amounts of carbonate, forsterite, phlogopite and serpentine. The forsterite ($2V = +83$ (‡); $+87$ (‡); $+86$ (‡), in places composes up to 25 to 30% of the volume of the rock, forming isometric crystals ranging from 0.02 to 3.5-4.0 millimeters. The serpentine occurs as pseudomorphs after the forsterite, and also as tiny flakes and plates located in fracture zones. Their structure is irregularly granular, porphyroblastic and lepidoblastic. The size of the grains varies from 0.01 to 2.5 millimeters.

The skarn marbles are dense, greenish, fine-grained rocks composed mainly of carbonate, diopside and tremolite. Epidote, clinozoisite, light mica, serpentine, quartz and an ore mineral are present in small amounts. The structure is granoblastic and in some places diablastic.

The quartzites among the carbonate rocks occur as small layers in the western and northwestern parts of the region. Their occurrence is most clearly manifested south of the Chonnam Mine, where a part of the lower strata of the Puktechen suite, more than 1,000 meters in thickness, is exposed on the flanks of a large synclinal structure. Here the lowest strata are composed of white, massive, fine-grained and medium-grained marbles, above which lie layers of quartzites up to 100 or 150 meters in thickness. The quartzites are white and milky-white, massive, more rarely somewhat bedded, fine-grained and very fine-grained, with an allotriomorphic and more rarely cataclastic structure; in addition to the quartz, they also contain fine lamellar aggregates of light mica. The total thickness of the series is 2,000 to 3,000 meters.

The series of interlayered marble and schists is exposed on the watershed between the Puktechen and Namdechen Rivers. If the points in the section at which the carbonate rocks are interlayered with equal amounts of mica schists are taken to be their boundaries, it may be said that the greatest thickness of this subsuite occurs on the upper reaches of the Chintonchen River, decreasing to 600 meters toward the south and southeast. The thicknesses of the individual interbeds of schist also decrease in these directions.

A characteristic feature of this subsuite is the frequent and thin interlayering of greenish and dark-gray micaceous and crystalline limestones. The thickness of the interbeds on the average varies from several millimeters to several meters. The individual layers of marble and schist may be traced for several kilometers laterally, their thickness being about 100 to 150 meters. The clearly expressed bedding in the rocks of the middle series of the Puktechen suite suggests a comparison between these and flysch deposits.

The micaceous and calcareous-micaceous schists are fine-grained, dark-gray and greenish-gray; their composition includes quartz, biotite, phlogopite, tremolite, carbonate, cordierite and more rarely feldspar. Among the accessory minerals are tourmaline, apatite, sphene, leucoxene and an ore mineral; the secondary minerals include chlorite, sericite and epidote. The structure is lepidogranoblastic, porphyroblastic and, when there is a considerable content of quartz, glomeroblastic.

The actinolitic marbles consist of frequently alternating dark-green and light-gray interbeds, ranging in thickness from several millimeters to several centimeters. Under the microscope the rock reveals a clear banded structure, consisting of bands enriched in carbonate and other bands with a high content of silicate minerals. The carbonate bands are characterized by a granoblastic structure. The bands with a high content of silicate minerals have a lepidogranoblastic structure and are composed mainly of porphyroblastic crystals of actinolite, up to 1.5 millimeters in size, and of a small amount of biotite.

The crystalline limestones are dense, fine- and medium-grained, white, light-gray and greenish in the contacts with the schists; their structure is usually granoblastic. In addition to calcite, they contain small amounts of quartz, tremolite, biotite altered to chlorite, and finely dispersed ore minerals.

The subsuite of bedded marbles is most widespread in the watershed between the Namdechen and Puktechen Rivers and forms outcrops in the vicinity of the Kapsan Mine, the village of Kymkwang, along the right bank of the Puktechen River, south of the village of Pkhogori and in the basin of the Ynkhynchen River.

Here there is a predominance of gray banded marbles, frequently alternating with a layer of gray, white and dark-gray color whose thickness ranges from fractions of a centimeter to six meters. In addition, white and dark-gray marbles, dolomitic marbles and dolomites are developed in the series. The dolomites and dolomitic marbles frequently contain tremolite, which in some places forms more than 20% of the rock's volume. The layers of tremolitized dolomitic marbles can usually be traced for some distance along the strike and as a rule show no bedding. The interbeds of micaceous schists are rare and thin; they appear only in a few places in the lower or upper parts of the series, and rapidly wedge out along the strike.

In the upper reaches of the Namdechen River, where these rocks extend southward from the Kapsan Mine for more than 20 kilometers, the subsuite may be divided into four groups of beds (upward from below):

1. Banded marbles with interbeds of white dolomites, a few tens of meters thick mica schists, and more rarely quartzite (up to 10 meters thick); 700 m.

2. Light gray and gray marbles, ranging from strongly banded to weakly banded. Massive white and light-gray dolomitic marbles and dolomites are less extensively developed; 800 m.

3. Dolomites and dolomitic marbles with tremolite; which are light-bluish-gray and gray, massive, and more rarely banded; 400 m.

4. Frequently alternating light-gray, light-bluish-gray and white dolomitic marbles and dolomites, with a predominance of strongly banded light-bluish-gray and light-gray marbles; 600 m.

These packs of layers may be traced quite clearly also in the southeastern parts of this region, except that here the mica schists and quartzites are absent from the section.

The thickness of the uppermost subsuite is 2,500 m.

The total thickness of the Puktechen suite in the area of the watershed between the Puktechen and Namdechen Rivers is very great, some 5,000 to 6,000 m. To the west of this area, the thickness of the suite gradually decreases.

The above-cited material shows that the section of the Puktechen suite in the region

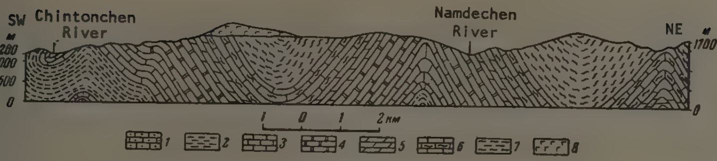

FIGURE 3. Geologic section through the area of the upper reaches of the Chintonchen and Namdechen Rivers.

1-6 -- rocks of the Puktechen suite; 7 -- rocks of the Namdechen suite; 8 -- Pliocene basalts; 1 -- massive marbles; 2 -- interlayered marbles and schists; 3-6 -- bedded marbles; 3 -- beds of banded marbles; 4 -- light-gray weakly banded marbles; 5 -- dolomites and dolomitic marbles with tremolite; 6 -- banded gray marbles.

under consideration generally contains many facies changes. In the western and northwestern areas (the upper reaches of the Ryusemul' and Chintonchen Rivers) the suite contains a large amount of terrigenous material, represented by interbeds of quartzites, mica schists and scattered grains of quartz. Toward the southeast the content of this terrigenous material decreases; the amount and thickness of the layers of quartzites and schists sharply decreases and the quartz fragments disappear entirely. These changes in facies show that the rocks of the Puktechen suite were transported from the west and northwest into the basin of sedimentation.

The clearly discernible, fine cyclical bedding in the rocks of the middle and upper parts of the Puktechen suite indicates that they probably belong to the class of flysch deposits, and were formed under marine conditions.

The degree of metamorphism of the rocks in the Puktechen suite varies in different places, and generally increases from northwest to southeast, becoming very great in the southern spurs of the Machenren Range. Here the marbles frequently contain forsterite, which disappears completely toward the northwest, giving place to tremolite and phlogopite.

THE NAMDECHEN SUITE[5]

The Namdechen suite is widespread within the territory under consideration and may be traced in the form of discontinuous bands from north south for more than 100 kilometers, from the latitude of Hyesan to the basin of the Namdechen River. The average width of this zone is more than 30 kilometers. This suite is well developed in the basin of the Rivers Namdechen, Hwansuvongan, Khyngol'-mul' and other places. The suite is represented mainly by quartz-mica schists and micaceous quartzites, containing smaller amounts of crystalline limestones and calcareous schists.

The Namdechen suite is conformable with the deposits of the Puktechen suite, thus forming synclinal structures of considerable size and complexity. One of these is located in the basin of the Namdechen River and extends roughly parallel to the longitude for more than 20 kilometers; its greatest width is 18 to 19 km. This syncline is composed mainly of quartz-mica schists and micaceous quartzites; crystalline limestone and calcareous schists are less extensively developed. The lower boundary of the Namdechen suite may be discerned by the typical and clearly distinguished rocks represented by chloride and biotite-muscovite schists, frequently interbedded with pinkish-white marble.

Another large syncline, composed of the schists of the Namdechen suite and the carbonate rocks of the underlying Puktechen suite, is known along the upper reaches of the Namdechen and Puktechen Rivers. The contacts between the suites is clearly discernible and represented by finely interlayered gray, white and pinkish marbles and chlorite-muscovite schists in the lower strata of the Namdechen suite.

The clear interrelationships between the rocks of the Namdechen and Puktechen suites has been observed in the basin of the Puktechen River. Here there are periclinal terminations of anticlinal folds composed of the marbles of the Puktechen suite and the overlying quartz-mica schists of the Namdechen suite.

The Namdechen suite is subdivided into three conformable series, the uppermost of which has a limited distribution.

The lower series is widely developed along

[5] The suite is named for the Namdechen River, which flows into the Japan Sea around Tanchen. The sections through the suite have been studied in the basin of this river.

the upper reaches of the Namdechen River, in the vicinity of Hochen, along the Hochengan River and its tributaries, and in a number of other places. This subsuite consists predominantly of biotite schists with silicate minerals (sillimanite, andalusite, staurolite and others), biotite, biotite-muscovite, chlorite-muscovite, biotite-sericite and sericite schists and micaceous quartzites.

The biotite schists with the silicate minerals are developed in the southern part of the region and form a steel-gray rock with a silk-like luster, a nodular and augen texture and a porphyroblastic, lepidogranoblastic structure. The composition of the schists includes quartz, biotite, sillimanite (or else andalusite, staurolite, garnet), and also plagioclase and varying amounts of muscovite; the secondary minerals include apatite, tourmaline, sphene, amphibole, epidote and zircon.

The biotite and biotite-muscovite schist composes extensive fields in the basin of the Hwansuvongan and Namdechen Rivers. The principal components of the schists are quartz, biotite, muscovite and plagioclase; the quartz and mica amount to about 85 to 90% of the rock. Chlorite, sericite, epidote, zoisite, tourmaline, apatite and an ore mineral occur in small amounts. Chlorite-muscovite schists consisting of chlorite, muscovite and quartz are closely associated with these schists. The chlorite and muscovite are secondary minerals and in a number of cases have been formed after the biotite, feldspar and silicate minerals. The structure of the schists is lepidogranoblastic, and in places microgranoblastic.

The biotite-sericite and sericite schists are fine-grained, and are encountered in the western regions in which the Namdechen suite is developed (the basin of the Khyngol'mul and Hwansuvongan Rivers). The main minerals in these schists are quartz, sericite and biotite, with varying amounts of chlorite and an ore mineral, as well as individual grains of tourmaline and sphene; the structure is usually lepidoblastic and granolepidoblastic, as well as blastopsammitic.

The micaceous quartzites among the quartz-mica schists form layers of various thicknesses, which are predominantly light pink and gray in color and are characterized by a fine-grained granoblastic structure and a massive dense texture. The greater mass of the rock consists of isometric grains of quartz, with calcium feldspar, sericitic plagioclase, biotite and muscovite occurring in lesser amounts; the accessory minerals are garnet, tourmaline, sphene and epidote.

The thickness of the lower series is variable and changes from a few hundred meters to 1,300 meters and more, gradually increasing toward the southeast.

The middle series occurs on the flanks of anticlinal structures along the Namdechen River and on the right bank of the Puktechen River. This series is composed of finely interlayered micaceous, microcline-containing schists, crystalline limestones, amphibolitic and zoisite-containing schists. The thickness of the individual interbeds varies from several centimeters to several meters, rarely reaching a few tens of meters.

Sections through this middle subsuite show many changes in facies. In the eastern parts of the region (around the Puktechen River) the most predominant are crystalline limestones, decreasing in occurrence toward the west.

The micaceous microcline schists are fine-grained, fine-lamellar, black, dark-gray and steel-gray; they consist of microcline, phlogopite and quartz, with tremolite occurring sporadically. In lesser amounts there is plagioclase, a mineral resembling epidote, garnet, sphene, tourmaline and an ore mineral. The average size of the grains is 0.1 to 0.2 millimeter.

The crystalline limestones are medium- and large-grained, white, gray and grayish-green; in addition to the carbonate, they almost always also contain phlogopite and tremolite, and sometimes diopside and olivine. Less frequently one encounters pure marbles that do not contain the above-mentioned minerals.

The amphibole schists are of limited distribution, and are encountered in the form of thin layers among the zoisite-containing and other schists and frequently are interbedded with crystalline limestones. These amphibole schists are fine-grained and medium-grained, consisting principally of brownish-green ordinary hornblende; in lesser amounts there is biotite, plagioclase, quartz, epidote, chlorite, muscovite, apatite and an ore mineral. Sometimes one encounters porphyroblastic, skeleton-like grains of garnet.

The zoisite-containing biotite and biotite-muscovite schists form a steel-gray or brownish fine-grained rock; they are encountered as layers of small thickness interbedded with the crystalline limestones.

The total thickness of the middle subsuite is no less than 250 meters.

The upper series occurs along the Namdechen River, south of the village of Rengvonri. This is composed of augen-like and nodular

biotite and biotite-muscovite schists, containing sillimanite, similar in outward appearance to the schists of the lower series characterized above. In addition to the schists, this subsuite contains micaceous quartzites. The thickness of the upper subsuite is about 500 meters. The total thickness of the Namdechen suite is no less than 2,000 meters.

The rocks of the Namdechen suite are metamorphosed sand-clay, and more rarely carbonate-clay and carbonate deposits. The degree of metamorphism of the rocks gradually increases from northwest to southeast. The wide-spread phyllitic biotite-sericite and sericite schists in the northwestern parts of this region are toward the southeast gradually replaced by biotite and biotite-muscovite schists. The mineral associations in these schists (sillimanite, plagioclase, biotite, garnet, etc.) indicate medium and high degrees of regional metamorphism. Olivine and diopside occur in the crystalline limestones.

The zonality of the metamorphism of the Namdechen suite corresponds definitely to the changes in its thickness and the nature of its deposits. According to our observations, from northwest to southeast there is not only an increase in thickness, but also a replacement of the terrigenous material by more fine-grained calcareous deposits. This may indicate that the sedimentation in the various parts of this region took place under varying conditions; the more shallow-water sediments were deposited in the west, and the deeper water sediments in the southeast (the basins of the Namdechen and Puktechen Rivers).

The age of the Machenren series has been determined as lower Proterozoic, on the basis of the fact that the youngest deposits, such as the Namdechen suite, are unconformably overlain by the Sinian deposits (in the basin of the Hochengan River).

The lower Proterozoic age of the Machenren series is also confirmed by the determinations of the absolute age of the crystalline schists in the Namdechen suite, for which an age of 1,600 to 1,620 million years has been arrived at by the argon method (N.I. Polevaya, VSEGEI).

The Machenren series extends beyond North Korea into the territory of Manchuria, where its analogues are the lower Proterozoic formations of the Liaohe system (crystalline schists, dolomites, quartzites) overlain by middle and late Proterozoic (Myuchzhen' and Fan'khe systems) rocks, and also by Cambrian deposits [5].

THE SINIAN SYSTEM

The deposits of the Sinian system are developed only in the north of Korea. Here they were first described in 1926 by the Japanese geologist S. Nakamura, who gave them a new and local name — the Sanvonian system.

The Sinian (Sanvonian) formations in Korea are most widespread in Southern Pyongyang province and its adjoining territory, where they lie with a sharp unconformity upon the rocks analogous to the Machenren series, or directly upon the granites and granite-gneisses of the Archean.

The Sinian deposits were not known earlier in the regions investigated by us. They extend through the western part of the region, in a zone some 10 to 25 kilometers wide, from the Pkhungsan River northward into the basin formed by the lower reaches of the Hochengan River and farther east beyond Hyesan (Khesandzhin) into the territory of China. The base of the Sinian system is everywhere composed of conglomerates. For example, on the left bank of the lower reaches of the Hochengan River the basal strata of the Sinian deposits lie upon the eroded surface of Archean granites and contain coarse clastic material formed by the disintegration of these granites. To the southwest of Pkhungsan the Sinian deposits unconformably overlie the rocks of the Namdechen suite, in the conglomerates of the lower strata of which, besides the products of erosion of the ancient granites, one also encounters pebbles of the Namdechen schists.

The most complete and thickest section of Sinian deposits in the territory under consideration is found in the eroded banks of the lower reaches of the Hochengan River, where they form almost continuous outcrops. Here the Sinian deposits are crumpled into a syncline trending north and south, with its hinge plunging northward, and by their composition may be subdivided into three conformable series.

The lower series is composed of conglomerates, gravelites, quartz sandstones and quartzite. Above these lie an almost completely uniform series of schists composed of argillaceous and calcareous-argillaceous schists and argillites, with thin interbeds of limestones near the top. Higher up in the section is a series of dolomites and limestones, in the lower part of which V.K. Putintsev has found specimens of the alga Collenia.

The lower series. A section through this series has been described along the left bank cut by the Hochengan River, 10 kilometers northwest of Chyungri. Here, upon the

eroded surface of the Archean granites, lie (from bottom to top):

1. Non-uniform granular cross-bedded, light-gray and rusty-brown quartz sandstones and quartzitic sandstones, containing many layers of gravilites and conglomerates of variable thickness (from 10 centimeters to 2.0 meters), enclosing pebbles of the underlying granites; 50 meters.

2. Light-gray and coral-pink, fine-grained cross-bedded quartz sandstones with interbeds up to 5.0 meters thick of fine platy black and greenish-gray shales; 220 meters.

3. Non-uniform granular cross-bedded, rusty-brown quartz sandstone containing hematite; 50 meters.

4. Quartz sandstones and quartzitic sandstones, cross-bedded and non-uniform granular, white and light-gray, with thin interbeds and lenses of gravelite and black shales; 250 meters.

The total thickness of the series is 570 meters.

The greater mass of the sandstones (85 to 95%) is clastic material represented almost exclusively by rounded quartz grains ranging from 0.2 to 2.0 millimeters in diameter. The sandstones in the lower layer of the series contain variable amounts of well-rounded grains of a brownish feldspar, and single grains of zircon and tourmaline. The heavy fractions, moreover, have been found to contain small amounts of amphibole, pyroxene, limonite, garnet, ilmenite and apatite. The cement, which holds the material together and more rarely fills pores and forms crusts, consists of tiny flakes of a mica-clay mineral and carbonates; their texture is randomly oriented, with some sign of layering.

The hematitic sandstones contain small amounts of clastic material (55 to 65%), the latter represented by angular, unsorted grains of quartz. Their structure is nonuniform granular, psammitic, with ferruginous cement. Prepared concentrates of this material show a content of hematite (sharply predominant), pyrite, zircon, apatite, amphibole, tourmaline and epidote.

Middle series. The most typical section through this series may be observed along the bank cut by the Hochengan River, some 7 kilometers northwest of Chyungri, where from bottom to top one may see:

1. Calcareous-argillaceous yellowish-white and light-gray shale; 150 meters.

2. Dark-gray clay shales; 170 meters.

3. Light-gray and white fine-grained limestones with thin interbeds of dark-gray clay shales; 30 meters.

4. Dark-gray and black clay shales with thin interbeds of white limestones; 60 meters.

5. Dark-gray and greenish-gray clay shales with thin veins of calcite; 20 meters.

6. Dark-gray, fine-laminar and fine-bedded clay shales and argillites; 300 meters.

7. Greenish-gray and black fine-laminar shales; 70 meters.

8. Dark-gray and black fine-laminar calcareous-argillaceous shales containing numerous fine interbeds of white and light-gray fine-grained limestone, 50 meters.

The total thickness of this middle series is 850 meters.

The mass of the argillites and shales is composed of tiny flakes and grains of clay-mica minerals, and fine-grained aggregates of brownish and yellowish substance. The silt-size fraction is represented by quartz grains of irregular, angular shape, up to 0.01 to 0.02 millimeter in cross-section. There is always a variable amount of tiny grains of pyrite and iron hydroxides, sometimes forming small aggregates (0.02 to 0.06 millimeter). The heavy fraction of the shales contains limonite, amphibole, pyroxene, ilmenite, sphene, garnet, tourmaline, zircon and apatite. The structure is pelitic, or blastopelitic; in some places it is spotty, because of the presence of irregularly distributed clay material.

The upper series of dolomites and limestones occurs in the center of the syncline. The lower part of this series consists of light-gray dolomites and dolomitic limestones, containing specimens of Collenia. In smaller amounts there are interbeds of quartz sandstones, marly shales and layers of dark-gray limestones. The upper part of the series consists predominantly of dark-gray, almost black limestones; when struck with a hammer they give off a sharp odor of hydrogen sulfide. In places among the limestones one encounters thin interbeds of greenish-gray and reddish-purple marly shales.

The dolomites and limestones are intermediate varieties. The carbonate rocks contain small amounts of argillaceous particles and fine grains of quartz from 0.01 to 0.4 millimeters in size, with sharply angular and web-like shapes. Pyrite grains are thinly scattered throughout.

The structure of the limestones and

dolomites is fine-grained, and sometimes brecciated, and the texture massive or fine-bedded. This banding is due to the interlayering of pelitomorphic and essentially calcareous interbeds.

The sandstones develop among the limestones as thin layers and are calcareous, medium-grained and fine-grained, uniformly light-gray and yellowish-gray. The clastic material that composes 55 to 65% of the volume of the rock is represented mainly by rounded grains of quartz from 0.1 to 0.6 millimeter in size; sometimes rounded grains of tourmaline are found. The cement of the sandstones is non-uniform granular and crystalline, consisting of aggregates of tiny grains of calcite, and more rarely of quartz and of limonite.

The marly shales are represented by fine aggregates of pelitic particles, fine grains of carbonate, quartz and micaceous minerals, and also by single tiny grains of pyrite. The structure is pelitic.

The thickness of the series of dolomites and limestones increases toward the north, the direction in which the syncline plunges, and at the boundary of China amounts to 500 meters.

The total thickness of the Sinian deposits within the regions under consideration is 1,920 meters.

The correlation table shows sections through the Sinian (Sanvonian) deposits of Northern China and Korea, together with a section along the lower reaches of the Hochengan River.[6]

The sections given in the Table are characterized by:

1. Weak metamorphism of the deposits, which lie upon older formations with a sharp unconformity.

2. The presence at the base of the Sinian deposits of coarse clastic formations grading upward into clay shales and thick carbonate deposits.

3. The presence in the middle part of the section (where it encompasses the entire Sinian, which is more than 1,000 meters thick) of a series of carbonate rocks containing the alga Collenia.

4. The widespread distribution of hematite-bearing sandstones and quartzites in the lower part of the Sinian deposits.

If the Sinian deposits are subdivided according to the type section through Northern China as cited by B.S. Sokolov and Yu.K. Dzevanovskiy [6], the deposits described in the lower reaches of the Hochengan River must be assigned to the Lower Sinian.

From the distribution of the Sinain deposits and the changes in their thicknesses it can be seen that within Ryangan province the basin of sedimentation was elongated approximately parallel to the equator; the material was carried into this basin primarily from the west. The basin gradually broadened toward the north, and the amplitude of its subsidence, and consequently the thickness of its deposits, also increased in this direction.

According to V.V. Belousov [1], along the lower reaches of the Hochengan River, on the Chinese side, there extended a zone of deep subsidence embracing the Lyaodun peninsula and the southern part of the Eastern Manchurian mountains. The greatest thicknesses are observed in the central parts of this trough (the In'shan mountains northeast of Peking), where they are more than 8,000 meters [4, 6]. Toward the periphery of the basin the thicknesses decrease.

In reviewing all the facts cited above, one may come to the conclusion that in Sinian times the area of the Hochengan River basin was a marginal part of an enormous region of subsidence adjoining the territory of Korea on the north.

This marginal position of the area under consideration, within the general region encompassed by the downward tectonic movements, is the reason for the absence of the upper strata of Sinian formations, which were deposited only in areas that underwent the most intensive and long-lasting subsidence; in this case these were the central parts of the above-mentioned basin.

CONCLUSION

These regular changes in the facies, thicknesses and degrees of metamorphism of the rocks in the Machenren series, against the general features of their location and the orientations of the principal folded structures, suggests that the rocks of this series were formed in an enormous synclinal trough extending north-northwest, with the depositional material being carried in from the west. From south to north this trough extended for more than 150 kilometers. Its western boundary approximately followed the line from Hyesan to Pukchen, and its eastern margin is

[6]The locations of the sections in Korea are shown in Figure 4; the sections by Pak Un Gen and Li Dze Kha are taken from their manuals, with the permission of the authors.

CORRELATION OF SECTIONS THROUGH THE SINIAN DEPOSITS IN NORTHERN CHINA AND NORTH KOREA[a]

Age according to author	Northern China. Hebey and Zhekhe provinces (after B.S. Sokolov and Yu.K. Dzevanovskiy, 1957)	Age according to author	Northern China. Lyaoning province, Lyaodun Peninsula (after Tsian Chun-Tso 1957)	Age according to author	North Korea. Ryangan province. Lower reaches of Hochengan River (after V.K. Putintsev and S.Ye. Sinitskiy, 1957)
Cambrian	Clay shales with trilobite fauna in the upper strata of the Lower Cambrian. Small hiatus.	Cambrian	Argillites. Lower Cambrian. Erosional gap.		
Upper Sinian	Limestones, sandstones and clay shales, thickness 150 m. Ferruginous sandstones; massive cross-bedded sandstones and clay shales, thickness 360 m. Erosional gap.	Upper Sinian	Marly limestones, marls, clay shales and quartzites, thickness 390 m. Quartzites with layers of ferruginous quartzites, thickness 351 m. Clay shales, thickness 113 m. Marls, marly limestones, thickness 145 m.		
Middle Sinian	Dolomites and limestones with with interbeds of clay shales; contain numerous Collenia, thickness 350 m. Clay shales and sandstones, thickness 250 m. Dolomites with shale interbeds, thickness 1,150 m. Clay shales, thickness 410 m. Small hiatus.		Limestones with Collenia and interbeds of clay shales, thickness 146 m.		
		Middle Sinian	Limestones and marly limestones with interbeds of clay shales, thickness 243 m.		
Lower Sinian	Dolomites, frequently siliceous with interbeds of silica and clay shales; first Collenia appear here, thickness up to 1,050 m. Quartzitic sandstones with cover of andesitic lavas, thickness 370 m. Black clay shales with thin sandstone interbeds, thickness 480 m. Quartzitic sandstones with numerous discontinuous interbeds of conglomerate, thickness 650 m.		Dolomitic limestones and limestones with Collenia, thickness 1,122 m. Limestones, marly limestones, clay shales and argillites, with interbeds of sandstones, thickness 1,064 m.	Lower Sinian	Dolomites and limestones with thin layers of sandstones and marly shales; alga (Collenia) encountered among dolomites in lower part; incomplete thickness more than 500 m. Clay shales and argillites with interbeds of calcareous clay shales and limestones, thickness 850 m. Conglomerates, gravelites, quartz sandstones and quartzitic sandstones with interbeds of ferruginous sandstones and clay shales; thickness 570 m.
		Lower Sinian	Quartzites and clay shales, thickness 653 m. Clay shales and argillites with interbeds of marls and quartzites, thickness 1,033 m. Conglomerates and feldspathic sandstone, thickness 265 m.		

Sharp nonconformity

Archean gneisses and schists.	Granites.	Granites and schists.

[a] Sinian system subdivided according to the section by B.S. Sokolov and Yu.K. Dzevanovskiy; subdivisions of stratigraphic column, distribution of facies and their ages after V.K. Putintsev and S.Ye. Sinitskiy.

CORRELATION OF SECTIONS THROUGH THE SINIAN DEPOSITS
IN NORTHERN CHINA AND NORTH KOREA[a]

Age according to author	North Korea. Southern Pyongyang province. Sangchen district (after I. Tateiva, 1931)	Suites acc. to author	North Korea. Southern Pyongyang province. Sangchen district (after I. Tateiva, 1931)	Suites acc. to author	North Korea. Southern Hwanhe province. Chamen district (after Li Dze-kha, manus. 1957)
Yandokskaya suite	Chloritic shales. Argillites and interlayered limestones and black phyllitic schists, thickness 500 m. Lower Cambrian (?).	Yandokskaya suite	Quartzites. Lower Cambrian		
Sodan'u suite	Gray limestones, thickness up to 100 m.	Sodan'u suite	Limestones and calcareous-micaceous shales; basal stratum of limestones with alga (Collenia), thickness up to 500 m.		
	Dolomites and limestones with rare interbeds of shale; alga (Collenia) encountered among dolomites in middle part; thickness 1,500 m.		Massive crystalline limestones with interbeds of clay shales, siliceous marls and quartzites; alga (Collenia) encountered among limestones in upper and middle part; thickness up to 1,600 m.	Sodan'u suite	Limestones and dolomites; alga (Collenia) encountered in middle part among dark-grey limestones; incomplete thickness 1,200 m. Clay shales and calcareous shales; interlayered with limestones in upper part, thickness 800 m.
Chikhen suite	Micaceous and calcareous shales with lenses and interbeds of quartzites and limestones, thickness 600 m. Fine-grained white quartzitic sandstones, thickness 20 m.	Chikhen suite	Micaceous shales with interbeds of limestones and quartzites; shales usually calcareous in upper part; thickness more than 600 m. Quartzites with interbeds of micaceous shales and limestones, thickness up to 100 m.	Chikhen suite	Quartzites with frequent wave-ripple marks; interbeds of calcareous shales and siliceous-argillaceous shales in middle part among quartzites; thickness 1,000 m.

Sharp nonconformity

Biotite-gneisses.	Granite-gneisses, mica schists with limestone interbeds.	Gneisses

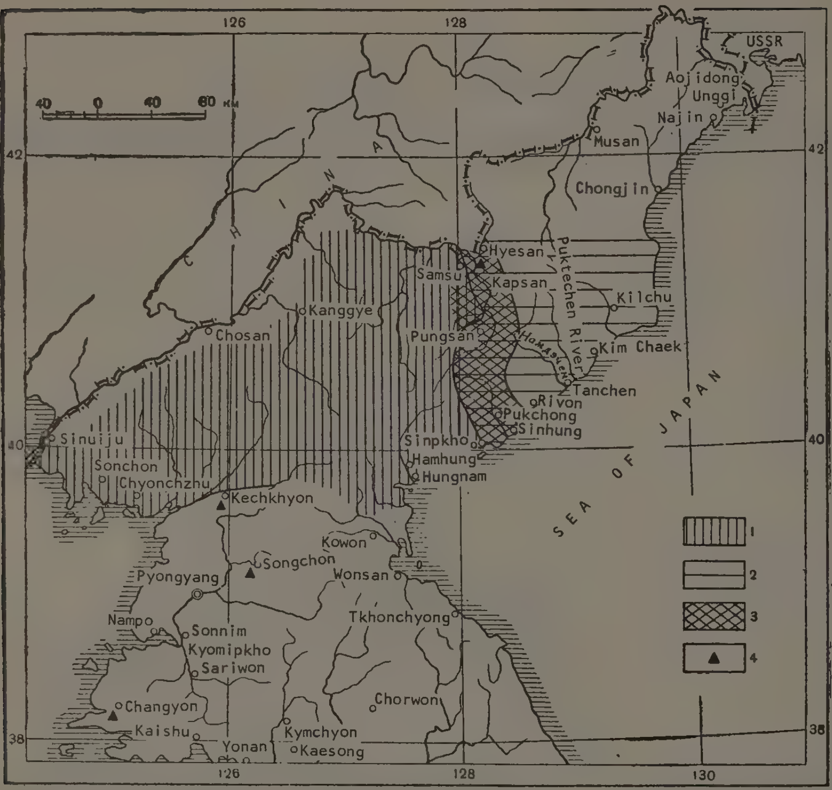

FIGURE 4. Sketch map showing the distribution of Precambrian rocks in North Korea.

1 -- area of Archean outcrops (region of Archean folding); 2 -- area of outcrops of the Machenren series (region of Early Proterozoic folding); 3 -- Hyesan-Rivon mobile zone; locations of the sections through the deposits of North Korea shown in the Table.

now buried beneath the waters of the Sea of Japan.

The rocks of the Machenren series, according to the conditions of their formation, belong to the category of geosynclinal deposits, as indicated by the following features:

1. The Machenren series clearly falls into three subdivisions, which correspond stratigraphically to the three sedimentary formations in typical geosynclinal regions. Thus the Sonzhin suite represents the terrigenous formation, corresponding to the initial stages in the development of the subsidence. The presence within this suite of a large amount of amphibolites, a considerable part of which are "ortho-deposits", testifies to intensive igneous activity during this time. The Puktechen suite corresponds to the time of maximum subsidence and represents the limestone formation. The Namdechen suite is the terrigenous formation formed in the concluding stages of subsidence.

2. The extensive development, among the rocks of this series, of flysch deposits characterized by a cyclical alterantion of rocks. Such deposits occur through a considerable part of the Namdechen suite, the middle and upper parts of the Puktechen suite and even part of the Sonzhin suite.

3. The enormous thickness of the deposits in the Machenren series, which in places (the Puktechen River basin) exceeds 10,000 meters.

4. The rocks of the Machenren series are

collected into linear folds of the geosynclinal type. These folds extend for a considerable distance and are characterized by clear anticlinal structures trending generally north-northwest (with an inclination to the submeridional direction). In particular areas the folds show a tendency toward overturning. Upon the major folds are superimposed smaller folds of secondary orders, all the way down to drag folds some few decimeters in amplitude.

The tectonic movements leading to the formation of the folded structures in the Machenren series were accompanied by intensive metamorphism of the rocks and by the intrusion of lower Proterozoic granitoids.

West of the lower Proterozoic geosynclinal region, composed of the rocks of the Machenren series, lies the margin of the exposed Archean basement of the Chinese platform. The Archean basement is composed predominantly of various granitoids; there are less abundant supercrystalline formations represented by granulites, gneisses and schists. In North Korea the rocks of the basement are widespread throughout the territories of Ryangan and Chagan provinces, and occupy an area of more than 50,000 km^2. They are undoubtedly older than the rocks of the Machenren series. This is indicated by the regional development of granitization and palingenesis in them, processes which are manifested locally in the deposits of the Machenren series, by the existence of a major structural unconformity in the orientation of the Archean and lower Proterozoic folded structures, by the increase in the amount of terrigenous material from east to west within the rocks of the Machenren series, and by a number of other facts.

The boundary between the lower Proterozoic geosynclinal region and the region of Archean folding is the so-called Hyesan-Rivon mobile zone,[7] more than 20 kilometers in width, which extends roughly north-south from the shores of the Sea of Japan toward the north, through the cities of Pungsan, Kapsan and Hyesan and beyond, into the territory of China. In Sinian times this zone was involved in downward movements, so that sediments were accumulated in it. After the Sinian period, the zone continued to exist as a region of intensive tectonic movements and repeated intrusions of igneous masses and extrusions of lavas, as well as the arenaceous sedimentation of coarse clastic continental facies.

Thus, in the area of North Korea under consideration, the Precambrian rocks may be divided into Archean, lower Proterozoic and Sinian formations, separated by major unconformities.

[7]This is the present author's suggested name; it may be considered as a zone of deep faulting.

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BRIEF COMMUNICATIONS

ERRORS IN MEASUREMENTS ON A FEDOROV STAGE, DUE TO BIREFRINGENCE IN GLASS SEGMENTS[1]

by

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In the manufacture of microscopes, objectives and condensers are examined carefully for birefringence. Manuals on microscopic methods of analysis mention this point and petrographers have become accustomed to the fact that lenses, located between nicols, should be free from mechanical stresses.

The possibility that birefringence might occur in glass segments was not considered and, as a result, a substantial number of stages with double refracting segments are being used.

Birefringence is induced by: 1) residual strains, observed in segments which have not been subjected to mechanical action, and 2) temporary strains, caused by the application and removal of pressure on the segment mounting.

In these segments, retardation, measured by an elliptical compensator, amounts to 6 to 15 millimicrons. With a thickness of 12 to 14 millimeters (radius of segment curvature is 13.5 millimeters) it represents an insignificant amount of birefringence on the order of 0.000001. (However, the corresponding amount for a standard, 0.03 millimeter thin section is 0.0002 to 0.0005).

This slight retardation, however, may have a marked effect on optical constants in a number of cases. Thus, nearly uniaxial quartz and apatite, when measured with double refracting lenses, may exhibit an axial angle as high as 40 to 45°; and errors in measuring the axial angle in feldspars may amount to 3 or 4°, 2 to 3° in phlogopite, 1 to 2° in muscovite, etc.

An inspection of segments from 20 Fedorov stages (three pairs in each), manufactured in the "Russian Gems" plant from 1949 to 1955, revealed that approximately only 10% of the segments had a retardation of less than 3 millimicrons; a retardation of 4 to 6 millimicrons was discovered in nearly two-thirds of the segments and 7 to 12 in one third. By varying the tightening of segment screws and raising the thin section with the pilot wheel until its surface is coincident with the intersection point of the stage axes, or, merely by applying pressure on the segment mounting, a substantial increase in retardation is produced.

An inspection of seven Leitz stages of two different models revealed that in those stages which have anchoring screws inserted into the segment mounting, retardation approaches 10 to 12 millimicrons. In those segments of Leitz stages in which the tightening of anchoring screws is limited by the thread length, and the screws exert a slight pressure against the stage because of weak springs beneath the screw heads, retardation does not exceed 4 or 5 millimicrons; for accurate measurements this must still be taken into account.

A number of questions arose in connection with these observations. Why does birefringence in segments bring about such gross distortions in measurable constants? If it affects the optical constants of quartz to such an extent, will it not similarly affect measurements of feldspars (with birefringence nearly equal that of quartz) and other minerals? Which of the optical constants determined on a Fedorov stage will it be necessary, therefore, to regard with suspicion? Is it possible to use similar stages for optical research and within what limits?

Let us examine the phenomena that take

[1] Ob oshibkakh izmereniy na Fedorovskom stolike, svyazannykh s dvuprelomleniyem steklyannykh segmentov.

place when light passes through a mineral placed between double refracting segments. These phenomena can be considered the result of the analysis of light passing through a group of arbitrarily oriented crystal plates, a problem repeatedly analyzed in crystal optics [2, 3]. As we know, when similarly oriented crystal plates are superimposed, the polarization plane is rotated and a change in retardation occurs; this change can be determined from Poincare's diagram [2]. Because of the small magnitude of double refraction in segments, rotation of the polarization plane may be disregarded. The retardation phenomenon in these plates, however, should be analyzed in its relationship to a Fedorov stage; that is, it should be taken into account that with the tilting of the "plates" an allowance must be made for the different directions which shift as the specimen is rotated around the stage axes. With superimposed plates, the synthesis of observations on a Fedorov stage produces a conoscopic figure which, in effect, acts as a sort of calculating machine, integrating the directionally different retardations of the plates within the cone limits.

This composite picture for different cases can be obtained with the aid of a skiodrome, or, by simulation, using thin plates of muscovite, for example. Skiodromes give a graphic illustration for a number of simple cases; for example, with the superposition of biaxial plates, it suffices to superimpose two identical skiodrome diagrams, in a position transverse to each other, thus obtaining a cross instead of two isogyres through the combination of vibrations which are alike in direction and opposite in sign.

However, for a specific case, it is more convenient to follow the path of simulation in qualitative investigations of phenomena as well as in quantitative determinations. The simplest way of illustrating the phenomena which concern us is by examining the conoscopic figure of some mineral with a Nikitin-Berek compensator introduced through the tube slit. Depending on the sign of the mineral and its position on the stage, convergence or divergence of the isogyres can be observed as the compensator plate is rotated through small angles. The use of this compensator, however, introduces some additional retardation which remains constant for all points of the mineral's conoscopic figure. If a calcite plate could be placed directly on the investigated mineral and together with the mineral examined through convergent light, a composite conoscopic figure would be obtained. It is interesting to note that the effect for these two conditions differs not only by an increase in retardation accompanying an increase in distance from the optic axis, but also by the direction of change. In the first instance (the compensator is introduced into the tube), the adding of retardation to a conoscopic figure of a biaxial negative mineral, increases the axial angle; in the second instance, it decreases the axial angle. This is understandable, because throughout the length of the Nikitin-Berek compensator there is an arrangement of γ calcite plates; when one of these plates (similarly oriented) is examined under convergent light, the direction of vibration along γ' is peripheral, but along α' it follows the radii of the conoscopic figure (compare the skiodromes for a uniaxial negative crystal).

From observation of the effects caused by the superimposition of very thin plates of uniaxial phlogopite, muscovite and thin sections of quartz, both in perpendicular and tilted positions to the optic axis, and sanidine, ground at a slight angle to the acute bisectrix, we arrive at the following conclusions.

The superposition of a biaxial plate on a uniaxial one, produces a biaxial conoscopic figure. If the plates have a like optic sign, 2V decreases, if opposite, 2V increases. If the two superimposed plates are biaxial, have coincident bisectrices and are alike in sign, the plate with the lesser birefringence decreases the 2V value of the plate with the greater birefringence; if their sign is opposite, 2V increases. The total value of 2V depends on the interrelationship of the axial planes.

This condition is abruptly disturbed and becomes false and lacking in symmetry, if the acute bisectrices of the biaxial plates, or, the acute bisectrix of one and the optic axis of the other, do not coincide but are at a considerable angle to each other. With these conditions, the position of the different optic axes changes to varying degrees: the conoscopic figure may become complicated, only one isogyre may remain, the other one simply disappearing.

For a quantitative determination of the retardation effect produced by segments on optic constants, let us visualize the indicatrix of a uniaxial crystal — the ellipsoid of revolution. Along the direction of the optic axis, perpendicular to the circular section, there is no double refraction, hence retardation is exactly zero. Retardation does occur, however, when the directions are not parallel to the optic axis, since the sections perpendicular to these directions are no longer circular. This retardation increases very slowly, however, with deviation from the optic axis for minerals with low birefringence (but becomes more rapid with increased birefringence). Thus, for quartz having $\gamma - \alpha = 0.009$, a standard thin section of d = 0.03 millimeters, and a direction that forms an angle of exactly 15° with the optic axis,

retardation amounts to only 12 millimicrons. This magnitude of retardation, however, may occur in segments. Thus, it can be compensated for and can produce extinction at an angle of 15°; this would correspond to an axial angle of exactly 30°. Similarly, retardation in biaxial minerals occurs in those directions which deviate from that of the optic axis.

The rate of change in birefringence and in associated retardations, increases as the distance from the diameters of the ellipse is increased. Thus, the larger the angle between the optic axis and the ellipse diameter (axes of indicatrix γ and α), the more rapid the increase in retardation and the less the displacement of the axis by this retardation increase.

In this manner, as a result of birefringent segments, compensation can occur in directions which give a retardation value of up to 15 millimicrons. These will be cones around the optic axes (eccentric to the optic axes because changes take place more rapidly in the direction of the acute bisectrix than in the direction of the obtuse bisectrix). These cones, which determine the maximum possible error, have dimensions that depend on: 1) the measured size of the axial angle, since the retardation rate change increases with an increase in V (half the axial angle, the interval to the ellipse diameter); 2) the birefringent power of the mineral's $\gamma - \alpha$; 3) thin section thickness (d) and the angle of inclination (α) between the optic axis and the thin section plane ($d_1 = d \cos \alpha$).

Let us further examine the ellipse with axes γ and α (Figure 1). Perpendicular to optic axis A, $\gamma' = \beta$, a circular cross section. Now let us compute the angle that γ'' and γ''' must form with γ' so that $\gamma'' - \beta = \gamma''' - \beta = 0.0005$, i. e., the angle which produces a retardation of 15 millimicrons with a thin section of exactly 0.03 millimeters (the same retardation as occurs in segments). Twice this angle represents the maximum by which the axial angle can change as a result of retardation in segments. Depending on the value of $\gamma - \alpha$ and 2V, the direction of γ'' and γ''' will form a greater or lesser angle with $\gamma' = \beta$.

If we draw a graph representing γ' as a function of angle α, equal to V, if $\gamma' = \beta$ (an elliptic function curve is obtained), it is possible to compute the magnitude of error for different values of 2V, providing the following data are known: the mineral's birefringence, thin section thickness and retardation of segments. Computations can be facilitated with the use of a nomogram developed by A. A. Lyapunov, I. A. Ostrovskiy and M. V. Pentkovskiy [1]. For very small changes in birefringence a computation can be made using the parametric function $X = \gamma \cdot \cos V$, $Y = \alpha \cdot \sin V$, and from coordinates X and Y calculating γ.

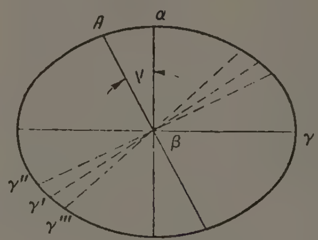

FIGURE 1. For determining γ' as a function of V.

Figure 2 illustrates the magnitude of the possible error for 2V, from 0 to 90°, for minerals with birefringence of 0.005, 0.009 and 0.030 with a thin section of 0.03 millimeters and a retardation in segments of 15 millimicrons.

Increasing the thin section thickness by two, for example, reduces the magnitude of error by two; conversely, decreasing the thin section thickness proportionately increases the error. In like manner, a retardation in segments of 6 to 7 millimicrons reduces the error indicated on the graph to 2 to 2.5 times. This magnitude of error represents the largest possible magnitude. In practice, it is impossible to calculate the exact magnitude of error.

In determining the orientation of the indicatrix, the magnitude of error changes in approximately the same manner. Here, however, as a result of superimposing birefringent segments, a variety of optic indicatrix "anomalies" can be observed.

Birefringence in segments can be detected in the following circumstances:

1) in a conoscope using a Fedorov stage while inspecting segments without a thin section,[2] a simulated conoscopic figure is produced in the shape of a cross (see 2, page 167) as a result of rotating the direction of vibration (appearing when examined between crossed nicols using any lens that has a markedly curved surface); the figure splits into two isogyres as the segment is rotated.

[2]First it is necessary to check for birefringence in the objective and condenser and for accuracy of adjustment of the nicols.

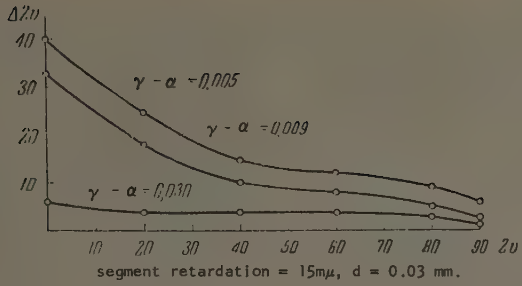

FIGURE 2. The maximum possible error of determination ($\Delta 2V$) of different axial angles ($2V$) for minerals having: birefringence so that $\gamma - \alpha = 0.005$, 0.009 and 0.030; a thin section of 0.03 mm; a retardation in segments of 15 millimicrons.

2) with the Bertrand lens disengaged, birefringence is indicated if slight clarification occurs as the segments are rotated around axes N, H and J; if, at the same time, a Nikitin-Berek compensator is introduced into the microscope's tube slit, two isogyres instead of a cross can be seen (with the plate in a horizontal position);

3) for rapid examination of segments without a microscope, a method can be used which was suggested by A. V. Shubnikov for observing conoscopic figures in a small ball made from an optically anisotropic crystal [3]; having inserted the segment between crossed polaroids and placed the source of light under one of them, we can see the same picture as in the conoscope using a Fedorov stage; in this case the segment functions both as a condensing lens and the observed object;

4) if the segment possesses birefringence, holding it in some definite position and turning a uniaxial mineral thin section by hand, for example quartz, will produce a conoscopic figure of a biaxial mineral (using a Fedorov stage) which will remain almost unchanged with rotation; in this case the isogyres do not converge in some quadrants or diverge in others, as is the rule in a conoscopic observation of a mineral; on the contrary, holding the thin section in any position and rotating the segment around the N axis, one can see that the isogyres converge, forming a cross which then again breaks down into two isogyres, i. e., the observed conoscopic figure is essentially determined by the optical properties of the segment.

CONCLUSIONS

1. Birefringence can occur in segments of Fedorov stages as a result of mechanical strains, producing retardation of about 5 to 15 millimicrons. The magnitude of the maximum possible related error in measuring the axial angle, can be determined from the graph in Figure 2.

2. The greatest distortions occur in measuring minerals with a small axial angle and low birefringence. This applies especially to abnormally biaxial minerals of average syngonies in which severe distortions of true values may be obtained. However, even measuring such minerals as feldspars, with axial angles of 40 to 70°, the error (in thin sections with a standard thickness of 0. 03 millimeters) can be 3 to 4° or more.

3. It can be assumed that as a result of birefringence in segments for which corrections have not been made, errors have been introduced not only in individual measurements (especially sanidine, tridymite, some amphiboles, etc.), but also in certain general conclusions: the significant size of the axial angle for abnormally biaxial minerals, the abnormal asymmetry of the optic indicatrix.

4. Evidently, in order to eliminate the possibility of an effect by the mounting on the segment glass, it is necessary to introduce changes in the manner of fastening segments in a stage. To accomplish this, it is recommended that the segment, when possible, be lightly anchored to the stage. (In the early stage models, such as Fyuss and Peterman, segments were merely placed into the mounting instead of being fastened to it).

During recent years, advances in the techniques of stage manufacture have been directed toward providing "mass production", "statistical determinations (pentaxial models), but not toward improving the accuracy of measurements. The manufacture of objectives having

long focal lengths, large magnification and special condensers, essentially allows an improvement in accuracy when employing the conoscopic method on a Fedorov stage. It is necessary to manufacture stages which, technically, could provide maximum accuracy.

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RELATION OF SPECTRAL BRIGHTNESS IN MINERALS TO DEGREE OF DISPERSION[1]

by

I. N. Belonogova and Yu. S. Tolchel'nikov

In connection with the recent use of aerial methods for geologic investigations, geologists have shown increased interest in the spectral reflectivity of natural materials. Data [1, 2] have appeared in literature describing the spectral brightness of a number of minerals and rocks and listing their properties, disregarding physical conditions. From the work of A. F. Fioletova [7], N. N. Sytinskaya [5] and others, it is known, however, that spectral brightness of rocks and other natural materials depends not only on chemical composition but also on physical conditions (e. g., dampness) and surface texture. In spite of this, factors affecting the spectral brightness of rocks and the regularity of its geologic effects, until recently, were almost unstudied.

In this report, results of a study of the relation between spectral brightness of minerals and their degree of granulation are examined. Related work has been conducted by Z. V. Zhidkova [4], O. P. Girin and B. I. Stepanov [2] on colored glass powders.

We determined the spectral reflectivity of minerals by measuring the spectral brightness coefficients $R_\lambda = f(\lambda)$ with a universal FM photometer, employing interference filters which give a narrower band of transmission than the usual gelatin filters. The color filters at our disposal enabled us to work in a spectrum range of 420 to 680 millimicrons, spaced at intervals of about 20 millimicrons. A baritized paper with a reflecting power of 85% was used for calibration.

The minerals chosen for investigation are among those having a pronounced color difference: quartz, microcline, garnet and epidote. Powder specimens, differing from each other in grain size, were prepared in the following manner: mineral crystals, cleaned of impurities, were ground up in an iron mortar and, by means of centrifugal scattering, divided into five fractions (measured in microns): 3000 to 1000; 1000 to 500; 500 to 250; 250 to 100; and less than 100. The iron in each fraction was removed with an electromagnet during the grinding process. The specimens were then decanted with water to remove extraneous dust and particles of the fine-grained fraction that may have adhered to the coarse-grained particles.

Spectral brightness curves (Figure 1) for the chosen minerals differed appreciably from each other. Thus, garnet had maximum reflectivity in a spectrum range of 660 to 670, epidote, 520 to 540 and microcline in a range of 600 to 660 millimicrons. The reflectivity of quartz, within the limits of the entire measured spectrum range (420 to 680 millimicrons), was the same.

The spectral brightness of all minerals increased throughout the entire spectrum range with the degree of granulation (graphs show all curves as being displaced upward). An increase in mineral brightness with a decrease in particle size is conditioned by increased dispersion of light [6] and by its decreasing retardation when passing through small particles. For such minerals as garnet and epidote, which in the massive state reflect little light, increasing granulation to 250 or 100 microns increases maximum

[1] O zavisimosti spektral'noy yarkosti mineralov ot stepeni dispersnosti.

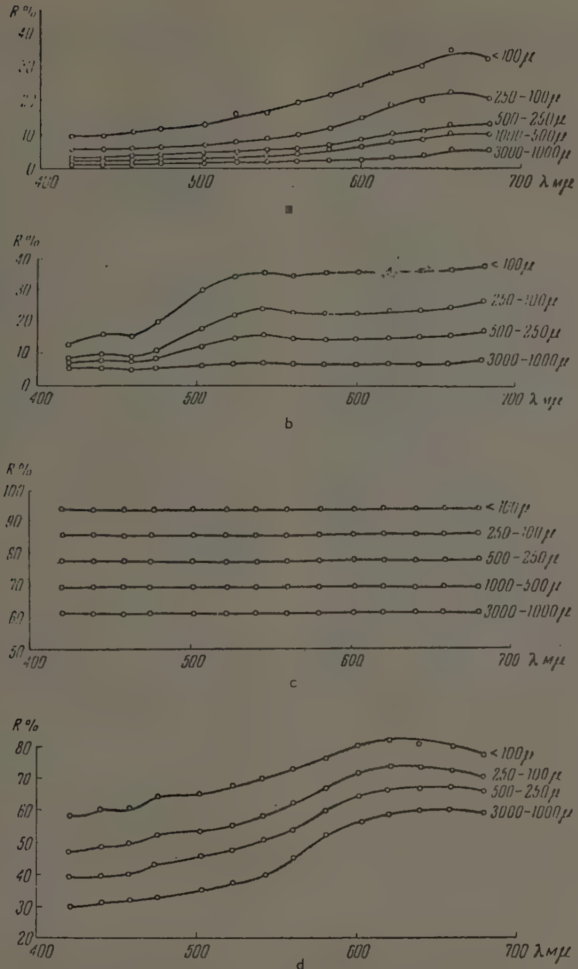

FIGURE 1. Spectral brightness curves for minerals with different grain size.

a - garnet, b - epidote, c - quartz, d - microcline

Table 1

Minerals	R_{max}/R_{min}				
	3000-1000μ	1000-500μ	500-250μ	250-100μ	< 100μ
Garnet	4.0	3.7	3.5	3.4	3.2
Microcline	2.0		1.7	1.5	1.5

R_{max} — luminosity in zone of maximum reflectivity
R_{min} — luminosity in zone of minimum reflectivity

reflectivity. A further decrease in particle size has some retardation effect on the increase in maximum reflectivity, although to a very insignificant degree. If maximum to minimum brightness ratios for microcline and garnet are compared, it can be seen that these ratios decrease with an increase the degree of dispersion.

This phenomenon can be explained in the following manner: with diffused reflection of light, the reflected beam consists of two components, the outer and the inner. The outer represents light which has been reflected by the surface of the investigated specimen. Its intensity is determined by physical properties at the boundary of the two media (the relation between indices of refraction of the specimen and those of the surrounding medium, and the geometric properties of the specimen's surface). The latter component is that part of the light beam which, having passed through a certain thickness of the mineral powder, is reflected back. The outer component, representing an insignificant portion of the total reflected light, has little effect on chromatic properties of an object; for substances, however, with strong selective absorption, the magnitude of the outer component, especially with maximum reflectivity, may exceed or be equal to the magnitude of the inner component. Thus, it can be assumed that some of the retardation effect on the increase in maximum reflectivity is a result of measuring the relation between the outer and inner components.

CONCLUSIONS

1. Spectral brightness of mineral increases with granulation.

2. Maximum reflectivity is more pronounced in granulated specimens (in our case less than 100 microns) of dark minerals.

3. In studying spectral brightness of minerals, their degree of dispersion should be taken into account. Under laboratory conditions, in order to obtain comparative data, all measurements must be made with specimens that have been granulated to a definite and equal particle size.

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AN EXPERIMENT ON RELATIVE AGE DETERMINATION OF GRANITES BY A THERMOLUMINESCENT METHOD[1]

by

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In our previous work [3] we cited results of determining the relative age of calcite and

[1]Opyt opredeleniya otnositel'nogo vozrasta granitov termolyuminestsentnym metodom.

other carbonates from thermoluminescence curves.

Related work was conducted by D. Saunders and J. Parks [5, 6] and is used in stratigraphic studies of limestone deposits. In contrast to our work, the above-mentioned authors employed radiation of the isotope Co^{60} for producing thermoluminescence; we, however, used ordinary X-ray radiation.

The phenomenon of mineral thermoluminescence can be explained in the following way: in many minerals, as a result of contamination, there are radioactive elements such as natural Ra, Th and U with the products of their decay, or radioactive isotopes of other elements. These radioactive elements, acting on minerals with their α, β and γ rays, cause those electrons located in the charged zone of the crystal to pass into so-called local levels in the space between the charged electron zone and the zone of conductivity. These electrons, as though stuck between the zones, can pass into the conductivity zone only through thermal action, and recombining with the luminescent nuclei, cause an emission of light.

Thus, these electrons store light gathered during considerable geologic time beginning with the formation of the mineral. The capacity for thermoluminescence is possessed by a majority of minerals. Only very recently formed rocks of the earth's crust do not display this capacity.

From the preceding discussion it is evident that intensity of thermoluminescence is related to the presence of radioactive inclusions in a mineral and to the mineral's age. The greatest thermoluminescence is displayed by fluorite, feldspars, calcite, zircon and other minerals.

For the determination of intensity of thermoluminescence, photoelectronic amplifiers are normally employed for picking up weak emissions of light. The photoamplifier is connected to an apparatus which, heating the mineral from room temperature to 350 or 400°, automatically records intensity of thermoluminescence for different temperatures. The intensity is recorded as a curve with one or several peaks. Low-temperature and high-temperature peaks, depending on the depth of local electronic levels, are obtained and recognized, inasmuch as a large amount of energy, i.e., heating temperature, is needed for the transfer of electrons from deep local levels.

The majority of minerals and rocks ordinarily give one normal high-temperature peak; this indicates that a mineral, from the time of its origin, existed under such temperature conditions that low-temperature levels had been deprived to a considerable extent of their electrons.

By exposing a mineral to some sort of radiation source (radioactive or quantum), it is possible to reestablish low-temperature local levels and to obtain characteristic peaks; comparing their magnitude with the peak for a standard of known age, it is possible to obtain an indication as to the age of the investigated mineral. In order to perform such an experiment only a small amount of the mineral is needed (30 to 40 milligrams).

It is necessary to note that mineral spectral emission, in the presence of thermoluminescence, is frequently varied: some minerals will thermoluminesce with a pale blue light, others white, orange or red. In order to obtain more accurate data, it is better, therefore, to compare those minerals which luminesce approximately in the same spectrum range.

The spectral sensitivity of the photoamplifiers is most frequently at a maximum in the range from 350 to 600 millimicrons, i.e., the sensitivity is greatest in the pale blue spectrum range; therefore it is helpful in order to obtain more accurate curves to place a filter in front of the photoamplifier aperture that will allow the passing of mainly the pale blue portion of the spectrum.

The following rock specimens from the Caucasus were studied:

1. Granite, Kardyvach region,

2. Diorite, Yatyrgvarta Mountain,

3. Rose granite, Fasnal Mountain,

4. Gray, uniformly textured granite, Sadon River,

5. Gray (chloritic) granite, Fasnal River,

6. Leucocratic Mi-granite, Bol'shaya Laba River – Zagedon,

7. Porphyritic granodiorite matrix, Malaya Laba River.

There are two references regarding the age of Caucasus granites: G. D. Afanas'yev [1] and Z. V. Studenikov and K. G. Knorre [4]. The latter authors point out that "among the investigators of North Caucasus magmatic rocks, there is no concurring opinion, not only concerning the age of this intricate complex, but even about attributing one or another separated group specifically to this complex."

G. D. Afanas'yev classifies all North Caucasus granitic intrusives into four age groups (in millions of years):

Caledonian intrusives — Silurian — Lower Devonian	320-290
Hercynian intrusives — Carboniferous — Permian	240-180
Mesozoic intrusives — Cretaceous.	120- 90
Cenozoic intrusives — Miocene — Pliocene	50- 30

Similarly, the following age data for individual intrusives can be cited as examples (from the potassium-argon method, in millions of years).

Rose granite, Fasnal River	120
Alaskite granite, Main Range	190
Granite porphyry, Khudes River	190
Granite, Sadon River	250-190
Plagiogranite, Main Range zone	255
Muscovite pegmatite, Malaya Laba River	310

In the work of Z. V. Studenikov and K. G. Knorre, all complexes are also divided into 4 age groups (in millions of years).

1. Main Range granite, Cambrian - Devonian. 450-270
2. Northern granite, Upper Paleozoic. 230-210
3. Neo-intrusives, Jurassic - Cretaceous 148- 80
4. Cenozoic complex 50- 15

Thus, the Fansal granite has an age of 210 million years, Sadon - 360 million years; Kardyvach region granites are neo-intrusives.

Our experiments on the above-listed specimens gave thermoluminescence curves shown in Figure 1.

The abscissa shows the powdered specimen's successive heating temperature; the ordinate, its thermoluminescence intensity. If age in millions of years, from 0 to 500, is shown alongside the intensity ordinate, it is readily seen that in the range of ±50 million years our data coincide with sufficient accuracy to those of the references.[2]

Curves 1 and 2 are obtained from preliminary exposure of the specimen to X-rays for a period of 15 minutes, inasmuch as these specimens do not exhibit any inherent thermoluminescence. All other curves result from inherent thermoluminescence.

The experiments conducted indicate that the thermoluminescent method, especially with further refinement, can be used for relative age determination of unknown rock series. These determinations can be used as a factor in their age classification.

The main advantage of this method is its

[2]The data obtained by the authors are close to the K-Ar-method results of age determination obtained by G.D. Afanas'yev for granites represented by curves 3-7 (see Figure 1). Russian Editor.

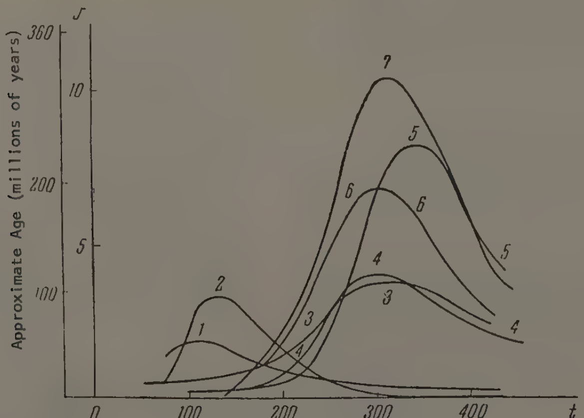

FIGURE 1. Thermoluminescence curves for granite.

1 -- granite, Kardyvach Mountain; 2 -- diorite, Yatyrgvarta Mountain; 3 -- rose granite, Fasnal Mountain; 4 -- granite, Sadon Mountain; 5 -- gray granite, Fasnal River; 6 -- granite, Bol'shaya Laba River; 7 -- granite porphyry, Malaya Laba River.

speed. In order to obtain a curve record, using a photographic method, it takes longer than 45 minutes; by using a paper tape-recording potentiometer, it takes only 10 or 15 minutes.

We wish to acknowledge A. M. Demin for supplying specimens from the Caucasus Mountains.

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REVIEWS AND DISCUSSIONS

ON CERTAIN VIEWS EXPRESSED IN PAPERS BY K. A. VLASOV AND THEIR ROLE IN THE PROSPECTING AND EVALUATION OF RARE-METAL PEGMATITES[1]

by

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Many Soviet geologists, in searching and prospecting for rare-metal pegmatites, are guided in their practical field work by the commonly accepted views of K. A. Vlasov [3-8] in regard to the structure and composition of rare-metal pegmatites. These views have been formulated most concretely as empirical conclusions from factual observations in K. A. Vlasov's famous work, "The Genesis of Rare-Metal Pegmatites"[7].

This article, on the basis of some rare-metal pegmatites of the Pamir, will attempt a critical examination of three of the most important views of K. A. Vlasov: 1) the dependence of rare-metal ore mineralization associated with replacement on the degree of differentiation of the pegmatites, 2) the influence of the morphological features of the pegmatites on the intensity of rare-metal mineralization and 3) the role of the enclosing rocks in the localization of the rare-metal pegmatites.

1. The main idea of K. A. Vlasov, which is found throughout many of his papers, is that there is a direct relationship between the intensity of rare-metal mineralization associated with replacement processes and the degree of differentiation of the pegmatites. Thus in prospecting and evaluating deposits, K. A. Vlasov recommends paying the greatest attention to fully differentiated rare-metal replacement pegmatites [6, 7]. In the above-mentioned article [7] he writes: "Large accumulations of rare-metal minerals are always associated with well differentiated veins, in which the processes of replacement are clearly manifested. In every pegmatite field there is a direct connection between the degree of differentiation of the pegmatite bodies and the concentration of rare elements within them, as well as the accumulations of rare-metal minerals." This assertion is the natural conclusion from K. A. Vlasov's concept of the formation of pegmatites in a relatively closed physicochemical system.

K. A. Vlasov's statement that there is a genetic connection between the processes of replacement and the degree of differentiation of the pegmatites has been opposed by some geologists for some time. But critical expressions of this opposition in print can be found only in papers by A. I. Ginzburg [10, 11], who writes that "a rigorous and regular connection between the manifestation of tantalum mineralization and the degree of differentiation of the pegmatite bodies does not exist. Tantalum minerals may be encountered both among highly albitized medium-grained pegmatites and high-albitized block-like or fully differentiated pegmatites" [11].

The authors of the present article, in studying the rare-metal pegmatites of the Pamir, have also encountered a number of facts which contradict the above-mentioned assertion of K. A. Vlasov. It will be seen from the brief description given below of the rare-metal pegmatites of the Pamir that not only the tantalum, but also the beryllium and lithium mineralization in replacement pegmatites, shows no relationship to the degree of their differentiation.

The rare-metal pegmatites of the Pamir are associated with intrusives of biotite — double-mica granites and granite-gneisses, which penetrate various gneisses and schists of underdetermined age. The rare-metal pegmatite fields are associated with exocontact intrusives and most frequently with the residual outcrops of their top.

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[1] O nekotorykh polozheniyakh v rabotakh K.A. Vlasova i ikh roli pri poiskakh i otsenke redkometal'nykh pegmatitov.

A characteristic feature of these pegmatites is the lack of block-like and fully differentiated varieties. The overwhelming majority of the pegmatites has a medium-grained structure, and pegmatites with a small-block structure (the dimensions of the felspar and quartz blocks varying up to 20 cm) being encountered much more rarely. Graphitic structures are observed extremely rarely. These pegmatite bodies show almost no zonality, and only in a few rare cases may one observe an increase in the dimensions of the mineral grains toward the center of the veins.

A rare-metal mineralization of practical interest is associated with intensively replaced and completely undifferentiated medium-grained and sometimes small-block structured pegmatites. Among the processes of replacement, the most widespread is albitization (the formation of a muscovite-quartz-albite replacing complex) and, to a lesser degree, greisenization.

The replacement embraces very large volumes of the pegmatites, as much as 70-80% of the entire vein body, and shows almost no changes with depth. We have observed intensively replaced pegmatites in which, for a distance of 100-150 m along the dip of the veins, the nature of the replacement and the rare-metal mineralization is completely unchanged. It must be stressed, moreover, that the most characteristic peculiarity of the rare-metal pegmatites in the Pamir is the fact that the replacement processes are superimposed to the same degree on pegmatites with both small-block and medium-grained structures. In addition, cases have been noted of the development of saccharoidal albite in the form of irregular volumes among pegmatoid double-mica granite-gneisses. This superimposition of the processes of replacement and the accompanying rare-metal mineralization on medium-grained pegmatites and pegmatoid granite-gneisses is easily explained if the pegmatite process is considered as occurring within an open system.

The brief description given above shows clearly that the rare-metal pegmatites of the Pamir cannot be fitted into the textural-paragenetic classification proposed by K. A. Vlasov [6]. The example of these pegmatites clearly shows a lack of any relationship between the processes of replacement and the degree of differentiation of the pegmatite or the magnitude of its rock-forming minerals.

2. K. A. Vlasov's assertion that "within every field of complex rare-metal pegmatites, the pegmatite veins that have the greatest economic value are represented, as a rule, by large bodies, mainly of oval form: columns (pipes), lenses, veins with swellings, etc." [7], is not correct in every case. This assertion is based on the fact that such bodies are usually better differentiated than bodies of tabular shape.

As noted above, the industrially valuable rare-metal pegmatites of the Pamir are characterized by a lack of differentiation. It follows from this that, in the case of this region, the form of the pegmatite bodies is of no significance in evaluating their content of rare-metals. In actual fact, almost all of the rare-metal pegmatites discovered in the Pamir up to the present time have the form of tabular veins. One of the pegmatite fields contains both bodies that are oval in plan and a thick tabular vein, the latter of which is more intensively replaced and contains a richer ore mineralization than the former.

In other provinces of rare-metal pegmatites (the Transbaykal, Kalba, etc.) the tabular veins are also of no less, and in a number of cases of even greater, practical importance than bodies which are oval in plan.

A. I. Ginzburg in his article "Some Features of Spodumene Deposits" [9] writes that the tabular bodies of replaced spodumene pegmatites are distinguished by their very great dimensions along both the strike and the dip, and by their uniform mineralization, and that they are of very great industrial value.

3. K. A. Vlasov's concept of the role of the enclosing rocks as criteria in prospecting follows from his idea that bodies which are isometric in plan are potentially the most valuable ore deposits. In his work "The Genesis of Rare-metal Pegmatites" [7] he writes that the most favorable enclosing rocks are those igneous and metamorphic rocks in which regular slaty cleavage is not strongly manifested and in which fractures of irregular form have been produced — gabbros and others. Such fractures are due to the formation of thick pegmatite bodies of rounded, columnar and lenticular form and of relatively short strikes. The most unfavorable enclosing rocks for the development of complex rare-metal pegmatites are schists formed from sedimentary rocks, which apparently before the injection of the pegmatite melt or solution had strong slaty cleavage.

All the rare-metal pegmatites discovered up to the present time in the Pamir occur in gneisses, schists and phyllites, all of which have good cleavage. Schistose rocks also contain the greater part of the industrially valuable rare-metal pegmatites of Transbaykal, Kalba and the Turkestan range. Hence this last assertion of K. A. Vlasov's is also contradicted by the observed facts.

We have been compelled to depart from

K. A. Vlasov's views and to set forth our own observations by the fact that Vlasov's works are extremely well known throughout the Soviet Union, and geologists engaged in searching and prospecting for rare-metal pegmatites orient themselves primarily upon his principles in their practical field work.

It may be noted that A. A. Beus also disagrees fundamentally with K. A. Vlasov. In his work on "Beryllium" [2] (an evaluation of deposits based on surveys and prospecting) he also considers rare-metal-replacement pegmatites to be the result of a further development of fully differentiated pegmatites.

A. A. Beus entirely fails to consider replaced medium-grained pegmatites with finely dispersed rare-metal mineralization, including small beryllium crystals that cannot be identified with the naked eye. Moreover such pegmatites are much more difficult to discover in prospecting than replaced fully differentiated pegmatites.

Without belittling the well-known industrial value of rare-metal fully differentiated replacement pegmatites, the present writers wish merely to stress, from the example of the pegmatites in the Pamir, that the genetic association between replacement accompanying rare-metal mineralization and the degree of differentiation of the pegmatite is not a law of nature, as would appear from K. A. Vlasov's writings, and is far from being universally confirmed.

Vlasov's above-mentioned statement that the rare-metal replacement pegmatites occur in close association with fully differentiated pegmatites will direct geologists who have little acquaintance with rare-metal pegmatites along a narrow and one-sided path, concentrating their attention only on fully differentiated pegmatites. This will result in great deficiencies in prospecting for rare-metal pegmatite deposits.

Our conclusions do not apply to non-replaced beryllium-muscovite pegmatites, in regard to which the above assertions of K. A. Vlasov and the recommendations of A. A. Beus are apparently fully applicable. We wish only to call particular attention to the fact that in prospecting for the evaluating rare-metal replacement pegmatites, special attention should be given not to the degree of differentiation of the pegmatites but to the processes of replacement within them, since it is with these that the rare-metal ore mineralizations that determine the economic value of the pegmatites are associated.

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ON THE SUBJECT OF K.N. KORZHINSKAYA'S ARTICLE, "THE STRUCTURE OF THE ORE FIELD IN A DEPOSIT OF MICACEOUS PHLOGOPITE"[1]

by

B. M. Ronenson

The "Bulletin of the Academy of Sciences of the U. S. S. R., Geologic Series," Number 6, 1958, contained an article by K. N. Korzhinskaya entitled "The Structure of the Ore Field in a Deposit of Micaceous Phlogopite." This article criticizes the presently accepted view of the stratigraphy and tectonics of this ore field and presents new concepts based on materials resulting from detailed geological surveys. But a careful reading of her article shows that on the basis of these "new" concepts the author presents a completely artificial interpretation of the quite well-known facts, and that her criticisms are based on a methodology that belongs to a long-past stage in the study of the geology of schist series. Inasmuch as such relapses still occur in geological investigations, it is the present writer's opinion that a brief critical review should be made of the basic methodological concepts on which K. N. Korzhinskaya bases her article.

K. N Korzhinskaya's main thesis can be reduced to the following:

1. Since each petrographic variety of schist is encountered only once in the stratigraphic section, all the repeated outcrops of the same rocks may be explained by processes of folding.

2. The structure of the deposit is one of extremely great complexity; there is a predominance of isoclinal folds, along with an undulation of the axis of folding, tectonic lensing, squeezing and cutting, facies changes in the beds along both the strike and the dip, and changes in the degree of metamorphism.

Let us consider each of these statements individually. Citing the paper "Objective Criteria for a Stratigraphic Subdivision of Precambrian Schists," K. N. Korzhinskaya writes: "B. M. Ronenson, on the basis of his previous conception of cyclical deposition in the Archean marine basin, came to the conclusion that the bed which is repeated in the complex isoclinal folding is an independent stratigraphic unit. . . . For example, the pyroxene-amphibole gneisses of the upper gneiss suite, which have been repeatedly crumpled into isoclinal folds, he divides into four independent strata and assigns them to different stratigraphic levels (Ac^{5a}, Ac^{6a}, Ac^{7a}, Ac^{8a}). Similarly he regards each outcrop of pyroxene-biotite, biotite-garnet and other gneisses as an independent stratum" (p. 76).

This cyclical structure of the sections through the schists has been established in the majority of regions where Precambrian rocks are developed. These facts are set forth in a number of works [2, 3, 5, 6],[2] the majority of which were published long before the article in question was sent to press. This cyclical alternation of schists of different composition may at the present time be considered not as a "preconceived idea", but as an objective regularity which opened great prospects for geological surveying.

In the case of the micaceous suite, this cyclical bedding is one of the most characteristic features. The section of this suite contains a rhythmic alternation of a limited number of types of schists, each of which corresponds to a definite element in the rhythm, and all of them together form a group of beds that occurs repeatedly in the section. Because of the overall directional nature of the process of sedimentation, each successive repetition (stratigraphic level) differs from the preceding one. The differences consist in the completeness with which the group is developed in each cycle, in the composition and structure of the individual elements of the cycle, in the thickness of the cycle as a whole and of their individual elements separately.

As proof of this statement, we may consider the beds of pyroxene-amphibole gneisses Ac^{5a}, Ac^{6a}, Ac^{7a}, Ac^{8a}), which K. N. Korzhinskaya regards as repeated outcrops of one

[1]Po povodu stat'i K.N. Korzhinskoy "Struktura rudnogo polya slyudyanskogo mestorozhdeniya flogopita."

[2]Mentioning only those works which are not contained in the list of references given by K.N. Korzhinskaya.

and the same bed. The relationships between the principal rock-forming minerals within it are given in Table 1, which shows the average ratio derived from a computation of the areas of the minerals in several scores of thin sections on the integration stage (calculations by G. F. Lazdenek).

may base a reliable correlation of sections in making geological surveys. This conclusion applies to major stratigraphic subdivisions in even greater measure than to minor ones. For this reason, of course, one cannot identify the lower part of the Slyudyanskaya suite, composed mainly of marbles and pyroxene-amphibole gneisses, with the upper part, composed predominantly of dolomites and biotite gneisses, as K. N. Korzhinskaya attempts to do.

Table 1

Relationships of the rock-forming minerals in the beds of the pyroxene-amphibole gneisses of the middle subsuite of the Slyudyanskaya suite

Bed	Average thickness in m	Plagioclase	Quartz	Monoclinic pyroxene	Hornblende	Ore minerals
Ac^{5a}	35	46,1	2,2	22,4	17,6	5,8
Ac^{6a}	50	28,7	7,8	26,4	32,4	1,0
Ac^{7a}	12	18,8	3,1	24,2	51,8	—
Ac^{8a}	36	32,5	0,8	2,2	61,8	1,2

NOTE: Comma represents decimal point.

It can also be shown that these strata differ not only in their thickness and in the relationships between the principal rock-forming minerals, but also in the composition of these minerals (in the Ac^{5a} stratum the monoclinic pyroxene is represented by diopside, and the plagioclase by oligoclase-andesite, in the Ac^{6a} stratum by salite and andesite, in the Ac^{7a} bed by hedenbergite and andesite, and the Ac^{8a} bed contains almost no pyroxene, while the plagioclase is represented by labradorite), as well as by the structure that is, by the number, position and thickness of the calciphyre interlayers.

One may similarly compare the other elements of the cycle (the beds of pyroxene-biotite, biotite-garnet and other gneisses) to which K. N. Korzhinskaya refers (Table 2).

The data cited above could be disputed by the argument that such changes are produced by facies transitions. But this argument also falls through if one considers the data given in Table 3, which shows the average composition of certain gneiss beds in various sections, which are separated by distances of about 2 kilometers along the strike of the beds (Section 1 in the Slyudyanka River valley, Section 2 in the lower part of the Uluntuy River and Section 3 on the upper reaches of the Zil'bermints River).

The general methodological conclusion that may be drawn from an examination of these peculiarities in the composition and structure of these crystalline schists is that almost every stratigraphic subdivision possesses a totality of marked indications on which one

This fundamental error — the interpretation of the section through the Slyudyanskaya suite — also involves incorrect conclusions regarding the tectonic structure of the region. In this case the natural concept of this structure as the flank of a major anticline which is completed by folds of secondary and tertiary orders and regularly broken by faulted dislocations [1, 4, 5] is replaced by an extraordinarily complicated reconstruction, which must have recourse to clearly unthinkable measures. Thus, for example, in sections C-D and E-F, which the present writer has drawn in Figures 4 and 5, the stratum of leucocratic biotite-gneisses in the southwestern part lies upon marbles and is intersected by pyroxene-amphibole gneisses, in the middle portion lies on pyroxene-amphibole gneisses and is overlain by hornblende-pyroxene-biotite gneisses, and in the northeastern part wedges out entirely.

In order to connect the flanks of the folds, the author has had to assume, on the one hand, the formation of zones of "squeezing of the material in the periclinal parts of the structures," where "the beds are collected into complex linear and disharmoniac folds, forming peculiar semi-permeable screens" (p. 75) and, on the other hand, to speak of "places of intensive tectonic compression," in which there is a "squeezing out of the material, accompanied by a greater differentiation of the individual layers and the

appearance of zones of cleavage and tectonic lensing with the formation of fractures along the contacts" (p. 76).

It is characteristic, moreover, that no factual proofs of the physical presence of faults or zones of cleavage are given in these parts of the sections. There are only references to A. I. Suloyeva, whose map shows the faults occurring in completely different places from those in which K. N. Korzhinskaya would have them, and to A. A. Sorskiy, whose paper actually refers to the complex of White Sea gneisses and migmatites of Karelia.

In conclusion, it must be said that in the

Table 2

Relationships of the rock-forming minerals in the beds of the biotite gneisses of the middle subsuite of the Slyudyanskaya suite

Bed	Average thickness in m	Plagioclase	Quartz	Micro-cline	Rhombic pyroxene	Biotite	Garnet	Graph-ite	Cordierite and sillimanite
Ac^{5e}	25	28,2	28,9	21,9	0,2	6,8	—	1,3	8,1
Ac^{5g}	36	32,7	42,5	9,8	3,1	6,0	—	1,0	0,1
Ac^{6b}	40	45,5	23,1	4,5	8,7	13,6	—	—	—
Ac^{7b}	8	43,6	20,4	3,3	18,8	9,0	—	—	—
Ac^{7c}	24	50,0	20,6	1,3	—	14,8	12,4	—	—
Ac^{7d}	28	73,7	6,6	1,8	9,0	2,1	—	—	—
Ac^{8b}	13	18,5	20,7	40,5	—	15,9	2,3	0,3	—
Ac^{8d}	15	22,9	41,7	10,5	2,2	7,3	2,5	1,2	10,8

Table 3

Change in the relationships between the rock-forming minerals along the strikes of the beds of different gneisses in the middle subsuite of the Slyudyanskaya suite

Gneiss	Bed	Section	Plagioclase	Quartz	Microcline	Rhombic pyroxene	Monoclinic pyroxene	Hornblende	Biotite	Garnet	Graphite	Cordierite and sillimanite
Biotite-garnet	Ac^{5g}	1	23,5	31,0	16,0	—	—	—	7,4	—	—	11,1
		2	30,0	29,3	20,7	—	—	—	7,3	—	1,7	9,0
		3	27,3	20,5	27,0	—	—	—	7,0	—	2,3	12,7
Pyroxene-amphibole	Ac^{6a}	1	29,2	3,4	—	4,8	27,4	33,7	—	—	—	—
		2	28,4	7,5	—	2,9	34,3	25,4	—	—	—	—
		3	22,4	2,6	—	2,3	24,2	47,2	—	—	—	—
Biotite-cordierite	Ac^{7c}	1	57,4	16,3	0,8	—	—	—	15,4	10,6	—	—
		2	50,9	22,2	1,0	—	—	—	15,8	10,4	—	—
		3	40,7	21,5	3,2	—	—	—	16,8	13,9	—	—

NOTE: Comma represents decimal point.

heat of her polemic the author has recourse to methods that are not acceptable for scientific discussion in print. Her article cites data from unpublished papers by M. M. Pabурov, Ye. P. Shchukina, Ye. P. Chuykina, F. V. Kuznetsova and B. M. Ronenson; she also distorts the sense of the authors cited by her, particularly when she states that N. B. Vassoyevich formulated his "idea of cyclical deposition primarily in reference to flysch and flysch-like series of coal deposits" (p. 70), or that P. V. Kalinin divided his crystalline zone into two subdivisions, one of gneiss and one of limestone (p. 69). Moreover the "copy from the geologic map by B. M. Ronenson, Mine 2 and Section" given in her Figure 6 (p. 77) has nothing in common with the map constructed by me, which was first published in March 1957 [5].

This "method" was adopted in order to "prove" that "according to B. M. Ronenson, all the beds compose a lenticular monoclinal structure of the ore zone, maintaining a constant thickness and composition in each bed" (p. 70), although in all my published papers [1, 2, 4, 5] my concepts of the structure of this district have been set forth with full clarity: "The principal folded structure of the Slyudyanskiy deposit is represented by a deep, narrow anticlinal fold with a northwest trend and a synclinal fold located to the southeast of it" [5, 14].

This article by K. N. Korzhinskaya also contains a number of other errors which cannot be excused on the grounds of lack of space. On the whole, it must be stressed that K. N. Korzhinskaya's attempt to present a new interpretation of the stratigraphy and tectonics of the Slyudyanskiy phlogopite deposit is not a success.

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CRITICAL REMARKS ON THE ARTICLE BY V. V. LAPIN AND N. M. KURTSEVAYA ENTITLED "DIFFERENTIATION OF SILICATE MELTS UNDER ARTIFICIAL CONDITIONS AND ITS GEOLOGICAL SIGNIFICANCE"[1,2]

by

B. I. Zlobin

Among the various problems of petrology that require solution, one of the most important is that of the mechanism of magmatic

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[1]Kriticheskiye zamechaniya k stat'ye V.V. Lapina i N.N. Kurtsevoy "Differentsiatsiya silikatnykh rasplavov v proizvodstvennykh usloviyakh i ikh geologicheskoye zhacheniye."

[2]Bulletin of the Academy of Sciences of the USSR, Geologic Series, No. 5, 1958.

differentiation connected with the crystallization of a magma. The principle of crystallizational differentiation suggested by N. L. Bower, who proposes a relationship between the evolution of a magma and the separation of the crystalline phases in the melt, is controversial, fails to explain many of the observed facts in nature in the field of petrology, and has given rise to a number of objections. Hence the importance of experimental investigations of this problem becomes clear.

The article by V. V. Lapin and N. M. Kurtsevaya describes the phenomena of chemical and mineralogical heterogeneity arising during the cooling and crystallization of a silicate melt. The experiment was conducted under the conditions of an industrial plant and involved the crystallization of a large volume of slag. The most interesting feature of this study is the crystallization of a homogeneous liquid slag from a water-jacket furnace; this slag provided a record of the appearance of non-homogeneity after crystallization. After analyzing their data in detail, the authors come to the conclusion that the non-homogeneity of the melt was determined crystallizational differentiation and that "thus differentiation occurring during crystallization (emphasis mine — B. Z.) of the melt leads to enrichment of the upper layers in the heavier and more easily melted minerals, which are separated in the later stages of the process." Nevertheless the factual material upon which the authors have relied does not lead to such a conclusion. Let us examine this material.

The silicate melt, which approximately corresponds to the composition of basic and ultrabasic rocks, placed in a casting ladle with a volume of 2.25 x 1.75 meters during the course of five days was crystallized into a block of the following composition: olivine (predominates), hedenbergite, sulfides, magnetite and glass. Mineralogical studies of the upper and lower parts of this block have shown that the olivine precipitate in the higher parts has a greater content of iron than the olivine in the lower parts. The authors conclude that "in the crystallization of the melt, the first to be separated is an iron-magnesium olivine with the approximate composition of 60% molec. Fe_2SiO_4 — 40% molec. Mg_2SiO_4. The remainder of the melt, which is enriched in iron and now has a lower content of magnesium, is concentrated in the upper parts of the ladle, where beneath the insulating crust a gas phase, forming a large gas cavity, accumulates. In these areas olivine with a higher iron content (up to 68% molec. Fe_2SiO_4)."

Nevertheless the table constructed from the data provided by V. V. Lapin and N. N. Kurtsevaya shows readily and convincingly that the more ferruginous composition of the olivine in the upper parts of the ladle is not due to the residual melt, which is supposedly enriched in iron and would appear to be displaced upward.

Chemical analyses of the upper and lower parts of the crystallized block show that there are no considerable differences in the content of iron between them; on the contrary, the figures here are very close to each other and the difference does not exceed 1-1.5%, which in view of the generally very high content of iron is a very slight magnitude. At the same time, the content of MgO in the lower parts of the block is four times greater than in the upper. Thus it is very clear that in these lower parts of the block, along with the increase in the magnesium content of the olivine, there is an increase in the amount of magnetite along with some decrease in the content of the olivine itself. As the authors have observed, the other differences in the mineral and chemical compositions of the upper and lower parts of the block are very small. Thus one is compelled to conclude that the higher magnesium content of the olivine in the lower parts of the block is due primarily to the increased content of MgO in these parts.

Components	Units of measurement	Top of slag, Specimen 102	Bottom of slag, Specimen 104
Fe_2O_3	Weight, %	4,44	5,60
FeO	Weight, %	44,01	42,52
MgO	Weight, %	2,42	9,52
Olivine	Weight, %	69,5	61,9
Magnetite	Weight, %	8,8	13,5
Fe_2SiO_4 in olivine	Molecules, %	68	60

NOTE: Comma represents decimal point.

The excess of iron in this case is eliminated in the form of additional magnetite. The formation of a more ferruginous olivine in the upper parts of the ladle was due to the relatively low content of MgO here, and for this reason was accompanied by a smaller amount of magnetite. As the authors observed, the magnetite is syngenetic with the olivine. All of these data suggest that the mineralogical differences between the upper and lower parts of the block reflect the chemical heterogeneity of the melt and are, in particular, determined by the molecular ratios of (Fe_2O_3 + FeO) and MgO. Hence in the upper parts of the block (Fe_2O_3 + FeO)/MgO = = 10.8; in the lower parts this ratio is sharply displaced toward the magnesium side and is no greater than 2.6.

By what processes was the bottom of the block enriched in magnesium? In this case fractional crystallization can scarcely be accepted as an explanation. If the more high-temperature magnesium olivine had been the first to crystallize and then had settled to the bottom of the ladle, one would observe a partial melting of this olivine and an increased content of this mineral in the lower parts of the block. According to the author's data, this is not the case. Movement of the residual melt enriched in iron into the upper parts of the ladle is also an unacceptable explanation (see Table).

The formation of a chemical heterogeneity in the melt owing to external factors is also excluded, since the authors note the absence of any magnesium furnace-lining in the ladle and stress the homogeneous chemical composition of the melt entering from the water-jacketed furnace into the ladle.

Thus it can only be suggested that the accumulation of Mg in the bottom of the ladle was due to some process occurring in the liquid slag during its cooling but before its crystallization. In any case, the reason for the appearance of a vertical heterogeneity in the melt was not connected with processes of crystallization and later gravitational separation of the solid phase, resulting in a displacement of the residual melt into the upper layers. The data presented by the authors suggests rather than the crystallization of the slag merely fixed the chemical non-homogeneity of the melt that existed in its liquid state.

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CHRONICLE

FOURTH SESSION OF THE CARPATHIAN-BALKAN ASSOCIATION OF THE INTERNATIONAL GEOLOGICAL CONGRESS[1]

by Ye.K. Lazarenko

The fourth session of the Carpathian-Balkan Association of the International Geological Congress was held from the 16th-29th of September, 1958, in Kiev and L'vov.

The Carpathian Association was founded in 1922 at the Thirteenth International Geological Congress held at Brussels, in order to unite the geologists of the Carpathian countries in their study of the Carpathian mountain system. This association included geologists from Poland, Rumania, Czechoslovakia and Yugoslavia. The first meeting of the Association was held in 1925 at L'vov and Borislav. Sixty-five delegates attended this meeting, which established the constitution of the Association and elected corresponding secretaries from the individual countries, members of the Association who were among the most distinguished students of the Carpathians: Dr. K. Tolvinskiy from Poland, Professor G. Makovey from Rumania, Professor R. Kettner from Czechoslovakia and Professor K. Petkovich from Yugoslavia.

The second meeting of the Association was held in 1927 in Rumania, and the third meeting in 1931 in Czechoslovakia. A fourth meeting was planned in Yugoslavia, but did not take place, and the work of the Association was interrupted until 1956. After this 25-year gap, at the Twentieth International Geological Congress in Mexico a resolution was adopted to renew the activity of the Association, transforming it into a Carpathian-Balkan organization and correspondingly expanding its membership. It was planned that the fourth successive meeting should be held in 1958.

[1]IV s"yezd Karpato-Balkanskoy assotsiatsii mezhdunarodnogo geologicheskogo kongressa.

The Carpathian-Balkan Association was established at the Twentieth International Geological Congress with the following states as members: the People's Republic of Bulgaria, the Hungarian People's Republic, the Polish People's Republic, the Rumanian People's Republic, the Soviet Union, the Czechoslovakian Republic and Yugoslavia. Corresponding secretaries were designated from each country to direct the activity of the Association: Professor E. Bonchev (Bulgaria), Professor E. Vadach (Hungary), Professor M. Ksenzhkevich (Poland), Professor G. Makovey (Rumania), Professor Ye. Lazarenko (U. S. S. R.), Professor R. Kettner (Czechoslovakia) and Professor K. Petkovich (Yugoslavia).

Two hundred fifty-five geologists, including 78 official delegates and 177 representatives of geological institutions, took part in the work of the fourth meeting of the Association.

Delegates from the following countries were present at the meeting: Bulgaria, 6 delegates headed by Corresponding Member of the Bulgarian Academy of Sciences Ye. S. Bonchev; Hungary, 6 delegates headed by Member of the Hungarian Academy of Sciences E. Sadetski-Kardos; Poland, 15 delegates headed by Corresponding Member of the Rumanian Academy of Sciences M. E. Filipesco; Soviet Union, 26 delegates headed by Academician D. V. Nalivkin; Czechoslovakia, 15 delegates headed by Dr. M. Bratislavskiy.

The meeting opened at Kiev on September 16th with welcoming addresses by the President of the third Session, Migel' Bratislavskiy (Czechoslovakia), and the President of the Ordkomitet of the fourth Session, Ye. K. Lazarenko. These were followed by welcoming addresses by the heads of the delegations from the various countries that are members of the Carpathian-Balkan Association, the First Deputy President of the Council of Ministers of the Ukrainian SSR, I. S. Senin, and the Deputy President of the Ispolkom of the Kiev Municipal Council of Workers' Deputies, G. I. Arkad'yev.

The following reports were read and discussed at the meeting: O. S. Vyalov (U. S. S. R.), "Tectonics of the Soviet Carpathians"; T. Buday, V. Zoubek, A. Mateyk, M. Magel' (Czechoslovakia), "Fundamental Concepts of the Structure of the Western Carpathians"; Ye. S. Bonchev (Bulgaria), "Tectonic Interrelationships of the Southern Carpathians and the Balkan Mountains"; F. Sentes (Hungary), "Tectonic Map of Hungary"; D. Patrilius, I. Motash, N. Blyakhu (Rumania), "The geologic Structure of the Marmaros"; Ye. K. Lazarenko (U. S. S. R.), "Basic Laws Governing the Formation of Minerals in the Soviet Eastern Carpathians"; M. R. Ladyzhinskiy (U. S. S. R.), "Oil and Gas Resources of the Soviet Eastern Carpathians"; B. V. Porfir'yev (U. S. S. R.), "The Present State of the Theory of the Origin of Oil"; E. Sadetski-Kardos (Hungary), "The Problems of the Carpathian Volcanic Mountains in the Light of the New System of Igneous Rocks"; D. Dzhushko (Rumania), "The Development of Volcanism in the Baya-Mar Region"; M. Ksenzhkevich (Poland), "The Paleogeography of the Northern Carpathians in Poland"; G. Svidzinskiy (Poland), "The Problem of Thrusts in the Flysch Deposits of the Carpathians"; I. Dumitrescu (Rumania) "Tectonic Map of Rumania"; E. Filipescu (Rumania), "Correlation between the Black Shales of the Flysch Deposits in the Eastern Carpathians and the Cretaceous Deposits of the Northern Carpathians" and A. Mateyka (Czechoslovakia), "On the Geology of the Central Carpathians"; V. I. Slavin (U. S. S. R.), "Fundamental Problems of the Formation of a Flysch"; L. Keresh (Hungary), "A Flysch Facies in the Deep Structure of the Hungarian Lowland" and I. Shvagrovskiy (Czechoslovakia), "The Neogene Deposits of Eastern Slovakia".

The delegates took part in a number of field trips. The observations made on these trips provided material for discussion of the geologic problems considered at the meeting. For example, on September 18 they took a trip by steamship on the Dnepr River to Kanev, where they became acquainted with the geologically unique region of the Kanev dislocations, and visited the grave of the great Ukrainian poet T. G. Shevchenko and placed a wreath upon it. On September 21, in the vicinity of L'vov, the participants at the meeting studied the outcrops of the Upper Cretaceous, sections through the Lower and Upper Tortonian, the Buglov beds of the Lower Sarmatian and various facies of Tortonian deposits.

On September 23-28 the delegates took part in a field trip along the route L'vov-Drogobych-Truskavets-Stebnik-Borislav-Skole-Svalyava-Mukachevo-Uzhgorod, and examined the zone in which the southwestern margin of the Russian platform connects with the Ciscarpathian marginal basin, as well as with the Carpathian folded geosynclinal region and the Transcarpathian basin (or interior basin). Between Drogobych and Borislav they observed the Miocene deposits (of the Stebnik, Galicia, and Vorotyshch series), and at Borislav along the river Tysmenitsa they saw the Miocene deposits (of the Vorotyshch series), as well as deposits of the Paleogene and Cretaceous. At Truskavets and Stebnik they observed details of the stratigraphic column of the deposits in the lower part of the Stebnik series and the upper part of the Vorotyshch series, and the section through the Miocene along the Vorotyshch River and the lower part of the Stebnik series; at Skole they saw the deposits of the Cretaceous and Paleogene; and between Nizhnyye Vorota and Podpoloz'ye they observed deposits of the Paleogene and Cretaceous and the tectonics of the Central Carpathian and Magura zones, not to mention many geological facts in other places.

At the concluding session, on 29 September, the meeting discussed and confirmed the changes and additions to the constitution of the Carpathian-Balkan Association and adopted appropriate resolutions.

Following recommendations by the delegation heads from Rumania, Poland and Bulgaria, the participants at the meeting agreed to hold the fifth session in Rumania in 1961, the sixth session in Poland, and the seventh session in Bulgaria.

The principal resolutions of the session are given below.

1. Tectonics. It was noted that in recent years certain results have been achieved that make it possible to understand the fundamental features of the structure of the Carpathian mountain system. Nevertheless the task still remains of determining the role of thrusts and the relationship between the individual parts of the Carpathian system, as well as its connection with the Alps and the Balkan Mountain systems. Solution of these problems will require simultaneous analysis of all the available materials and construction of tectonic maps of the Carpathian and Balkan countries.

2. Stratigraphy. The meeting took note of certain achievements in the study of the Jurassic, Cretaceous, Paleogene and Neogene deposits, particularly in regard to flysch formations. Many problems of stratigraphy, however, cannot be solved without drawing upon material from the adjacent countries, so that there are still no unified stratigraphic subdivisions of the Triassic, Jurassic, Cretaceous and Tertiary deposits, particularly those of the Neogene.

In the immediate future it will be necessary to develop a unified scheme of stratigraphic subdivision of the Mesozoic and Cenozoic deposits, and to examine the paleogeography of the separate major regions of the Carpathian and Balkan mountain systems, as well as methods of mapping the flysch deposits.

3. Problems of igneous activity and the formation of minerals. In recent years certain important laws governing the distribution of igneous rocks and minerals associated with them have been discovered. Achievements have also been made in studying the metamorphic rock complexes of the Carpathians, particularly the Marmaros massif. But there are still many deficiencies in the solution to these problems: the petrogenesis, stratigraphic subdivision of the metamorphic rock complexes; insufficient use has been made of methods for determining the absolute age of rocks; and there is no single system of Carpathian metallogeny.

Examination of these problems is one of the first tasks in the geologic investigation of the Carpathian-Balkan mountain system.

4. In the geology of oil and gas, significant results have been achieved which have expanded the area of potential oil-bearing rocks, increased resources, and made it possible to approach a solution of the problems of the conditions of formation of oil and gas deposits. But the theory of the origin of oil and the formation of oil deposits in the Carpathians has been little developed, mainly because of the small extent of the investigations in oil geology, oil-bearing rocks and the conditions of oil migration.

5. Problems of mineralogy and geochemistry, and in some countries also problems of Quaternary geology and geomorphology, have not received sufficient attention in the work of geologists in the Carpathian-Balkan countries. In the future it will be necessary to expand the work done in these areas.

6. To coordinate the investigations made within the scope of the Carpathian-Balkan Association it was decided to organize certain permanent committees: a) tectonics (under the chairmanship of the representative from Czechoslovakia), b) stratigraphy, paleogeography and paleontology (representative from Poland), c) igneous activity and petrology (representative from Hungary), d) mineralogy and geochemistry (representative from the U. S. S. R.), e) hydrogeology (representative from Bulgaria), f) geologic mapping (representative from Rumania).

7. To organize and prepare stratigraphic dictionaries for each country, and in 1963 to publish a "Stratigraphic Dictionary of the Carpathian-Balkan Mountain System," and also to commence preparation of mineralogical, paleontological and micropaleontological reference books on the Carpathians and the Balkans. The responsibility for preparing the dictionary and the reference works was given to the corresponding secretaries from each country.

8. To increase the amount exchanges among geologists of the Carpathians and the Balkans in connection with current geological investigations, the elaboration of particular geological problems, and consultations and lectures on regional geology in the corresponding Carpathian and Balkan institutions of higher education.

9. To place at the head of the agenda for the next meeting an examination of the state of preparation of the composite geological and tectonic maps.

The delegations from Bulgaria, Hungary, Rumania, Poland and Czechoslovakia expressed their thanks to the government of the Soviet Union and of the Ukrainian SSR for their excellent organization of the fourth session. This session achieved great results in familiarizing geologists with the structure of the Carpathian Mountains, facilitated the exchange of ideas and experience in their scientific work, and also strengthened the ties of scientific fellowship between the peoples of the Carpathian and Balkan countries.

The work of the session was carried on in an atmosphere of sincerity and friendship between the delegates of the various countries.

AN OPEN LETTER TO SOVIET GEOLOGISTS[2]

by

G. A. Knyazev and Yu. A. Vinogradov

The oldest scientific archive in this country, the Archive of the Academy of Sciences of the U. S. S. R., possesses the largest collection in the world of manuscripts bequeathed by workers in science and engineering.

The Archive contains about 450 personal bequests and about 1,000 collections of manuscripts of Members of the Academy, Corresponding Members, Professors, Meritorious Workers in science and engineering, and other distinguished scientists of our country.

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[2] Otkrytoye pis'mo sovetskim geologam.

An important position among these is occupied by manuscript bequests from geologists. At the present time the Archive contains the personal bequests of 22 geologists, including 15 Academicians. Those of the greatest value for the history of geologic science are the bequests of Academicians V. N. Severgin, N. I. Andrusov, A. D. Arkhangel'skiy, V. I. Vernadskiy, I. N. Gubkin, the former President of the Academy of Sciences of the U. S. S. R. A. P. Karpinskiy, A. V. Pavlov, S. S. Smirnov, and others.

Manuscripts of Professors N. V. Bayarunas, A. V. Pavlov, A. N. Ryabimin and other geologists of our country, both Soviet and pre-Revolutionary, are preserved in the Archive and studied by our historians of science.

Unfortunately, in recent years the Archive has received bequests from only three geologists. The archivists of the Academy of Sciences are still faced with an enormous amount of labor in searching out and preserving posthumous manuscripts. It may be remembered that throughout the history of the Academy, 28 Academicians were elected in the specialty "geology", but only in the case of 15 of them were their posthumous manuscripts more-or-less fully preserved. Most of the bequests of these deceased scientists have still not been discovered. Certain of these personal collections were for various reasons not bequeathed to the Archive and have been lost to science.

The bequeathing of personal remains by scientists to the Archive of the Academy is a completely voluntary matter. But unfortunately the relatives or other heirs of the given scientist do not understand the importance and necessity of preserving such posthumous manuscripts. Some of them simply do not know where to send such personal effects, and others believe that their home provides adequate conditions for their preservation. This opinion, however, is not correct. Only the Archive of the Academy of Sciences of the U. S. S. R. is properly equipped to preserve fully the manuscripts inherited from scientists, to describe them scientifically and use them for the benefit of science.

The Archive will accept for preservation manuscripts of scientific works and working materials pertaining to these, documentary material characterizing the biography and activity of the scientist, autobiographical manuscripts such as memoirs, diaries, and literary productions, illustrative material such as photographs, drawings and sketches, scientific and other correspondence, reviews, excerpts from the works of other persons, and frequently also works by other authors that were included among the materials possessed by the given scientist. All such materials in combination constitute the bequest of a scientist.

In regard to materials accepted for preservation from the heirs, the Archive strictly fulfills all the conditions that may sometimes have been set in handing over the bequest. For an established period of time, the heirs retain the right to honorary authorship in the case of publication of the scientist's manuscript.

The Archive also accepts for preservation personal collections from the scientists themselves. Such materials are accepted and worked over according to all the established rules. They can be used for any purpose only upon written permission from the scientist himself who has made a gift of his personal materials to the Archive.

The Archive makes no charge for such preservation. At various times the Archive of the Academy of Sciences of the U. S. S. R. has received for preservation the personal materials of Academicians V. M. Komarov and S. A. Zhebelev, Corresponding Member of the Academy of Sciences V. N. Beneshevich, and others. Academician Ye. N. Pavlovskiy and Corresponding Member of the Academy of Sciences T. V. Yerenshtedt and other scientists have transmitted part of their personal materials to the Archive.

All scientists and geologists of the Soviet Union, regardless of their place of residence, are requested to cooperate in the preservation of the manuscripts left by outstanding Soviet geologists by transmitting them to the Archive of the Academy of Sciences of the U. S. S. R. They are asked to communicate to the Archive the location of such personal collections or individual manuscripts, and also to make use of this opportunity to transmit their own personal materials to the Archive of the Academy of Sciences of the U. S. S. R.

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